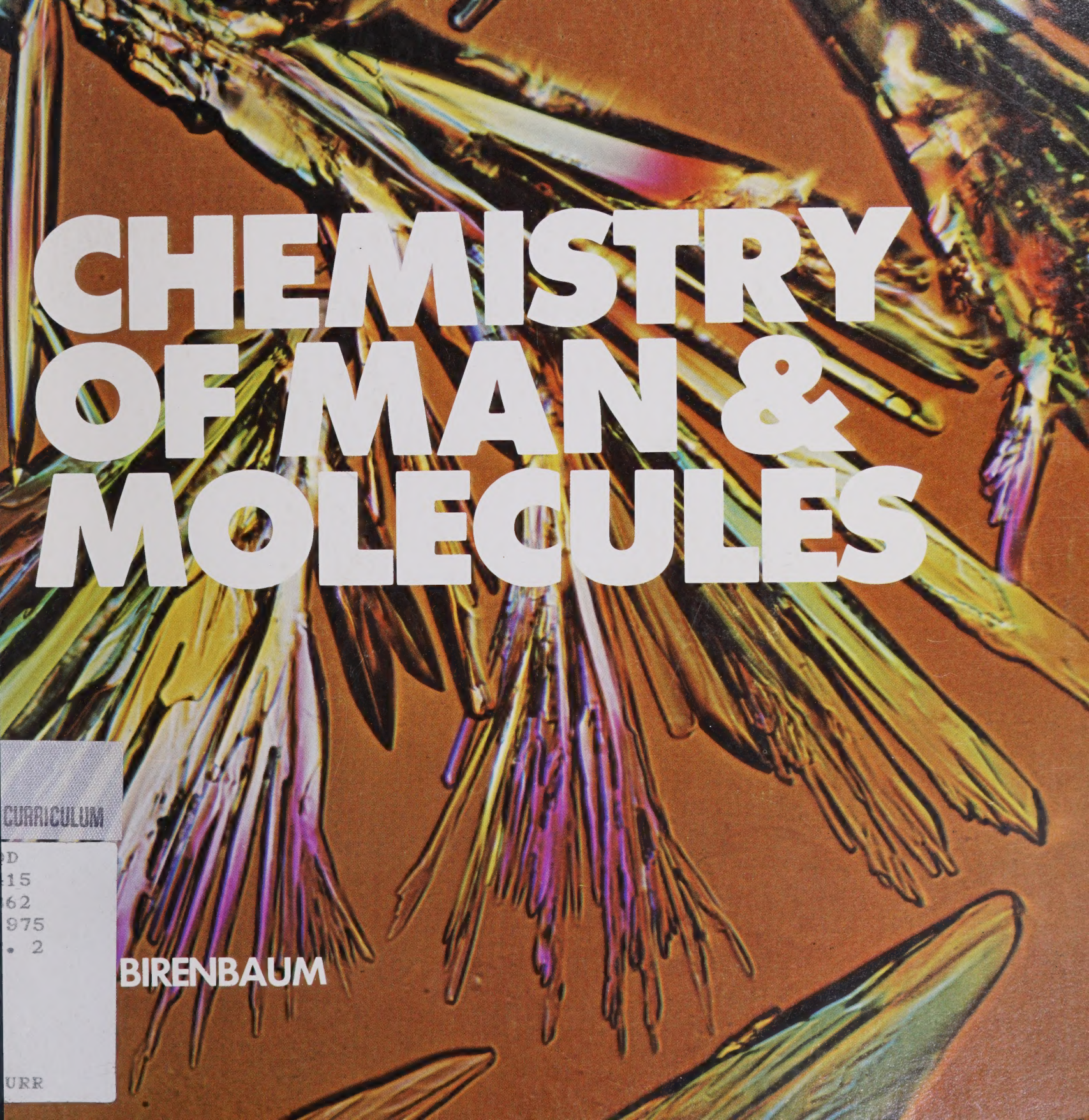

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CHEMISTRY OF MAN & MOLECULES

LOU BIRENBAUM

The Book Society of Canada, Limited
Agincourt, Canada

This booklet is dedicated to Sylvia, my mother, who saw only its very beginnings. She never stopped learning, and taught me a little of that art.

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ISBN 0-7725-2002-X

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Further titles are under consideration.

The design on the cover of this booklet was produced by placing sections of penicillin crystals between two pieces of polaroid and photographing them through a microscope. These crystals are made up of millions of penicillin molecules, whose structure is shown in Figure 2-6 on page 16. The technique for taking such photographs is described in *Chemistry of Photography* in this series.

Meet *Motor homonculus*! His photograph is on the previous page. *Motor homonculus* is a model designed to show the approximate proportions of the brain which control specific body functions. The greater the amount of brain used to control a part of the body, the larger is that part in the model. When molecules in the form of medicines are taken into the brain, they can greatly affect the way in which it works.

Design/Brant Cowie

Artwork/Frank Zsigo

Printed in Canada by The Bryant Press Limited

2 3 4 5 6 7 80 79 78 77

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Acknowledgments

Permission to reproduce illustrations is gratefully acknowledged below. Care has been taken in the preparation of these acknowledgments; the publisher would appreciate being informed of any errors.

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K. Ashcroft 3-3, page 23 (upper), 7-3, 10-2
Dr. A.G. Hendrickz 7-5
Hoffmann-La Roche Ltd. 8-1
Holt, Rinehart & Winston, Inc., New York, (*Human Physiology*, Morrison *et al.*, © 1967) 8-2 (adapted)
Merck Frosst Laboratories Cover, 5-5
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C.V. Mosby Co., (*Textbook of Physiology*, Tuttle, W.W., and Schottelius, Byron A., 1965) 1-10 (neuron)
National Cancer Institute of Canada 3-8
Ontario Attorney General's Forensic Science Laboratory 11-1
Ontario Science Centre Title page, 1-16, 1-17, 7-5
W.B. Saunders Co. (*Function of the Human Body*, Guyton, Arthur C., 1961) 4-1
Weldman, A. Page 52

Author's acknowledgments

I wish to acknowledge the following for their help in the preparation of the manuscript for this booklet: Dr. Samuel Birenbaum (for reading the manuscript, offering advice, and for checking the medical aspects), Dr. Allan Fergus (for reading Chapter 8), Norman Holt (my editor at The Book Society), Mrs. Annette Friedman, Ms. Susan Judge and Ms. Claudia Straka (for their rapid typing), Ronald Goodlin (for his assistance with preliminary drawings), and Mrs. Sheila Birenbaum and Ms. Lesley Higgins (for proofreading the manuscript).

Also, for their encouragement throughout the preparation of this booklet, I should like to thank: Abe, Ike, Grace, Marilyn, Shelley, Rhonda, Michael, David, Brian, Neal, Otto, Marv, Don, Sandy and Stacey.

Lou Birenbaum, November 1974

To the teacher

What is a "drug"? There are many answers to this question. In this booklet the student is acquainted with the fact that drugs are molecules; the theme that these molecules have specific unique chemical features pervades the whole booklet. Some of these features include molecular structure, chemical and physical properties, and the action of molecules on the body.

In order that the student may appreciate the uniqueness of each drug and its action on the body, the booklet first briefly describes how the body works. It is the author's intent to describe the beauty and extreme complexity of the human body and how molecules can affect it.

It is hoped that *Chemistry of Man & Molecules* will help students to become more aware of the molecules that enter the body from numerous sources, for instance in prescription medicines, in over-the-counter products (vitamins, antacids, cough preparation), and in foods. This awareness can be emphasized if students visit pharmacies and laboratories, read widely and write to government agencies enquiring, for example, about regulations for food additives.

Where possible, experiments and projects have been included for students to perform. These activities have been written with an "open-ended" philosophy in mind; that is, students are encouraged to use their own ingenuity and creativity to elaborate on activities. In Chapter 3, for example, they can find out how to make a smoking machine. This activity alone may compel some students to create a complex, motorized, multi-cigarette smoking machine. Many of these activities can, in fact, lead students to enter "science fairs."

Ours is truly a "drug age." It is hoped that students, from working with this booklet, will realize some of the beneficial effects of molecules—*and* some of their potential dangers. Questions are raised which should promote discussion both inside and out of school. For instance, the final chapter poses the question "1000 Einsteins or 1000 Hitlers—where are we going?" All of society is faced with this question. What are the answers?

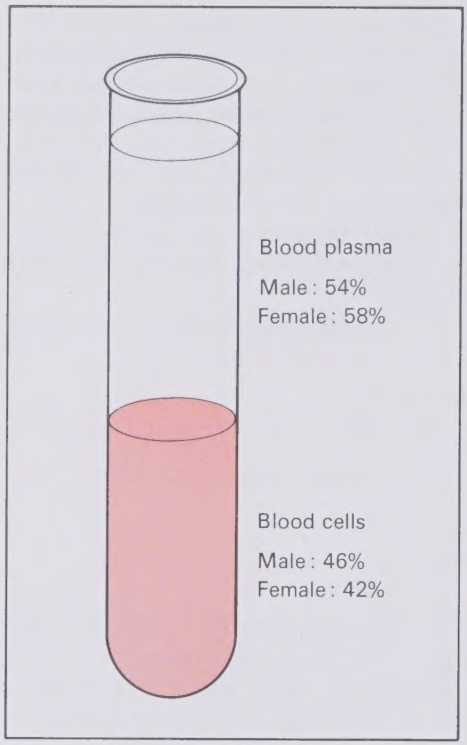


Figure 1-1. Tube containing blood that has been spun at high speed (centrifuged). You can see the proportion of cells to plasma. The list tells you more about blood.

COMPOSITION OF BLOOD

Blood plasma
Males: 54% by volume
Females: 58% by volume
pH: 7.3 to 7.4 at 38°C

Red blood corpuscles
Males: 46% by volume, 5 400 000 per mm^3
Haemoglobin: 15.6 g per 100 cm^3 blood
Oxygen capacity: 20.9 cm^3 per 100 cm^3 blood
Females: 42% by volume, 4 900 000 per mm^3
Haemoglobin: 14.2 g per 100 cm^3 blood
Oxygen capacity: 19.0 cm^3 per 100 cm^3 blood

White blood corpuscles
6000 per mm^3 of blood

Platelets
250 000 per mm^3 of blood

Table 1-1 CHEMICAL MAKEUP OF THE BODY

Element	Mass (%)
Oxygen, O	62.00
Carbon, C	20.00
Hydrogen, H	10.00
Nitrogen, N	3.00
Calcium, Ca	2.50
Phosphorus, P	1.14
Chlorine, Cl	0.16
Sulphur, S	0.14
Potassium, K	0.11
Sodium, Na	0.10
Magnesium, Mg	0.07
Iodine, I	0.014
Iron, Fe	0.010
	99.244
Trace elements	0.756
Total	100.000

1

The human body

How much do you think you are worth? It used to be that chemically the human body was valued at 98 cents. This was pretty deflating to some egos. But the *Chemical and Engineering News* has reported that "at current chemical prices, the adult human body is worth $3.50".

And now there's even better news. Biochemist W. D. Noteboom of the University of Missouri says that this estimate did not take into account the value of human blood—which he said is worth $130 to $170 per litre. Since an adult male has about five litres of blood, source of precious, life-saving *serum* (see Figure 1-1), this alone would be worth "an absolute minimum of roughly $650." Add $650 to $3.50 and you get $653.50, a gain over the old 98-cent price of something like 700 per cent!

Man was concerned with keeping himself healthy long before he put a price tag on his body. A prominent mythical being, Aesculapius, the son of Apollo, was said to have made "house calls" as a physician as early as 3000 B.C. The emblem of Aesculapius, the single serpent on a staff, is still used as a medical symbol all over the world.

Among early manuscripts is a scroll, called the "Papyrus Ebers" (see Figure 1-2). This papyrus is 30 cm wide and over 76 metres in length and dates from about the sixteenth century Before Christ, about the time of Moses. It contains remedies and methods for conjuring away diseases.

Man continues to find new ways to keep fit. Researchers in laboratories around the world seek molecules to prevent cancer, heart attacks, and a variety of ailments. People eat "health foods," are conscious about food additives, and join health clubs in an effort to care for the body.

The aims of this booklet are to study the effects of molecules on the body and to study some characteristics of these molecules. First you should review what a molecule is. You will also need to know a little about the mechanism of your body.

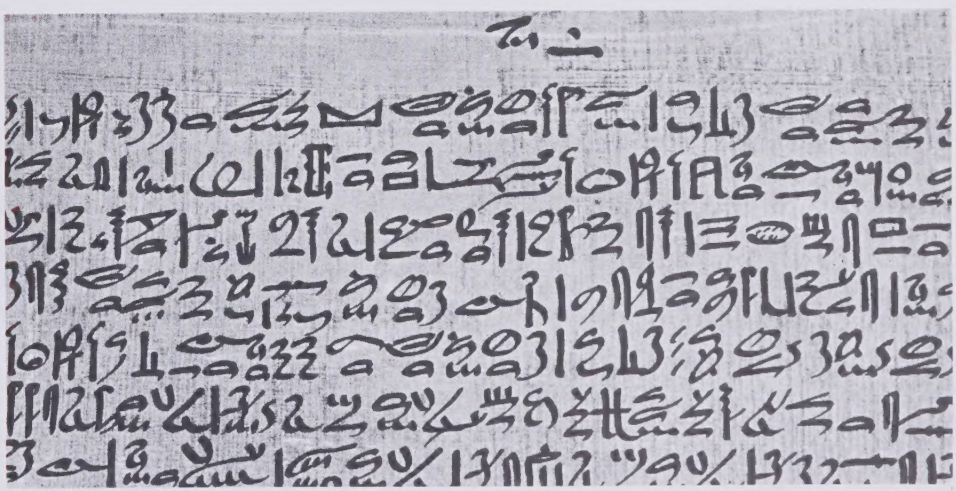


Figure 1-2. This part of the Papyrus Ebers contains a herbal remedy for headaches.

What is a molecule?

H_2 may be written as H—H. The — indicates that one pair of electrons is being shared between two hydrogen (H) atoms.

A molecule is a collection, large or small, of atoms. An atom, you will recall, consists of a nucleus containing protons and neutrons. (The only atom without a neutron is hydrogen.) In the atom there are also electrons. The simplest atom is the hydrogen atom, which contains a proton and an electron. When two hydrogen atoms "meet" each other they will join (bond) if the conditions are favourable. These two bonded hydrogen atoms are called a "molecule"—a hydrogen molecule. In the language of chemistry we write this as $H + H \rightarrow H_2$, where H_2 is the formula for the hydrogen molecule.

The hydrogen molecule of only two bonded hydrogen atoms is indeed a small group of atoms. However, there are numerous larger groups of atoms. For example, the water molecule is a group of two hydrogen atoms and one oxygen atom bonded in a certain way to give the structure H_2O. An example of a larger union of atoms is the molecule often used in windshield wiper fluid to prevent your windshield fluid from freezing in winter. This molecule contains four hydrogen atoms, one carbon and one oxygen atom, uniquely united to form methanol (methyl hydrate). See Figure 1-3. Its formula is CH_3OH.

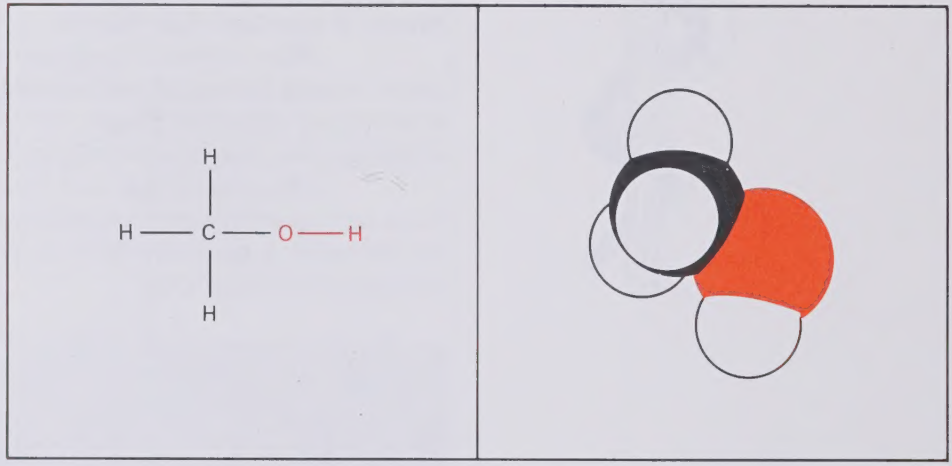
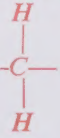


Figure 1-3. Molecule of methanol (methyl hydrate). The presence of O—H in organic molecules is denoted by "-ol" in the name, and the presence of  *or (—CH_3) is indicated by "methyl."*

Another familiar collection of atoms forms the octane molecule. Have you heard the "high octane power" commercial of a fuel company? The octane molecule has the formula C_8H_{18}. Each molecule contains twenty-six atoms, specifically bonded (Figure 1-4).

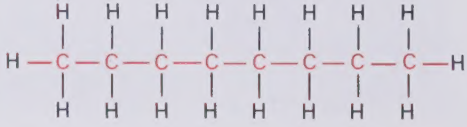


Figure 1-4. The octane molecule. The "oct-" in octane shows the presence of eight carbon atoms.

Often the union of atoms takes a circular or cyclic pattern, as in Figure 1-5. Cyclohexane is the starting material for the manufacture of nylons. A convenient representation for this molecule is indicated in Figure 1-6. This six-sided figure (hexagon) represents the cyclical union of six carbon atoms. It is assumed that, since each carbon atom can unite with possibly four other atoms, then the twelve remaining atoms in this molecule are hydrogen atoms.

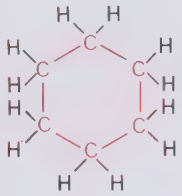


Figure 1-5 (near right). The cyclohexane molecule. "Cyclo-" indicates a circular or ringed structure, and "-hex-" indicates the presence of six carbon atoms.

Figure 1-6 (far right). Cyclohexane—a convenient "skeletal" form of Figure 1-5.

What does the union in Figure 1-7 represent? It shows six carbon atoms united in a circular way, but one of the unions (bonds) between two of the carbons is different. This union is called a double bond. How many hydrogen atoms are there in this molecule? If you answered "ten," you are correct.

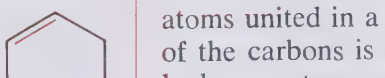


Figure 1-7. C_6H_{10}: a cyclic molecule with a double bond in it.

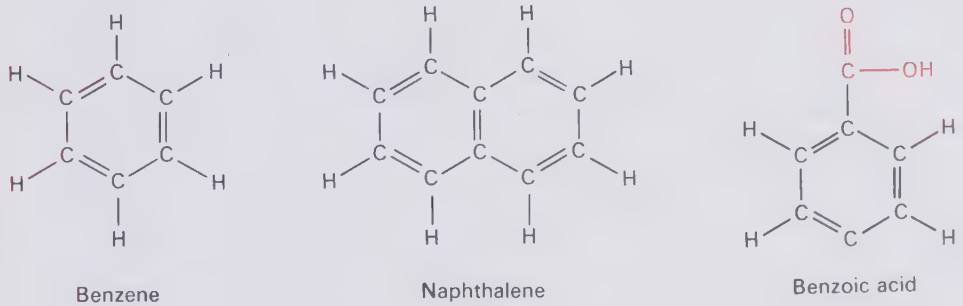


Figure 1-8. Benzoic acid, benzene and naphthalene molecules. The "-oic acid" indicates the presence of the COOH group in molecules.

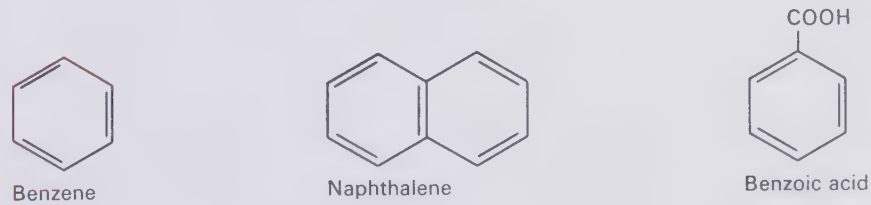


Figure 1-9. Convenient skeletal forms of the molecules in Figure 1-8.

Figure 1-8 shows some other groups of united atoms; these molecules are more conveniently written as in Figure 1-9. Throughout this booklet you will find such representations for some of the numerous molecules which act on the body. Note: *these molecules are unique unions of atoms.*

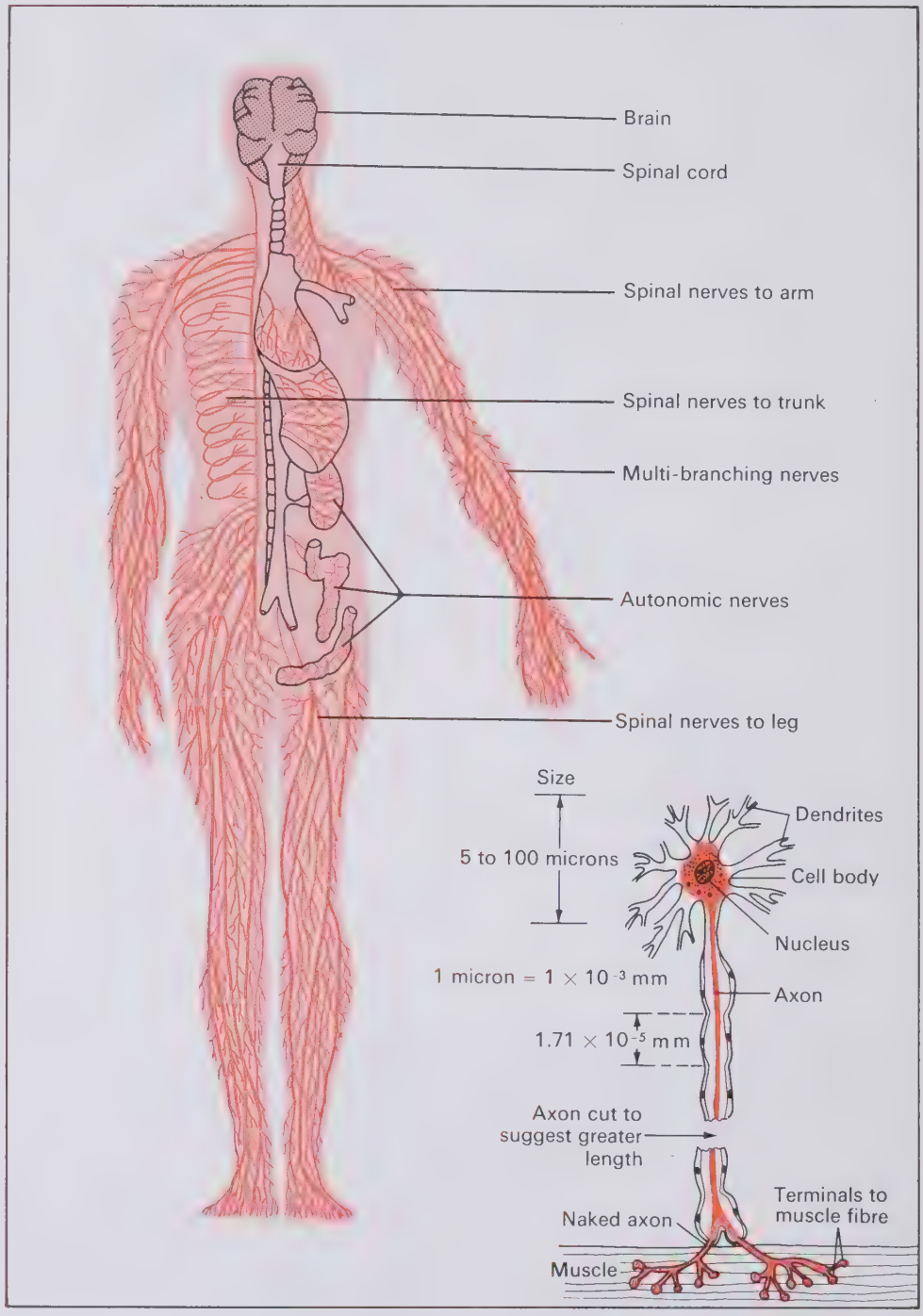


Figure 1-10. The nervous system. Your nervous system is built up of microscopic nerve cells, or neurons. The small drawing is of a neuron leading to a muscle.

The body has 1 000 000 bits of information travelling through it at any one time.

In the human body the brain is the centre of a miraculously intricate communications network unifying the body (Figure 1-10). We are, indeed, "a bundle of *nerves*." A variety of information is carried along highly specialized cells called *neurons* (as shown in Figure 1-10) which make up nerves. It is along this system of "roads" that "messages" are carried *electrochemically*. That is, part of the mechanism is electrical, and part is chemical. Stimulation of the neuron cells allows sodium ions, Na^+ (a sodium atom which has lost an electron), to pass more freely through them. While Na^+ enters the cell, potassium ions, K^+, leave the inner parts of the cell. This exchange of ions spreads to adjacent areas like a wave, as illustrated in Figure 1-11. This spreading is called the "nerve impulse."

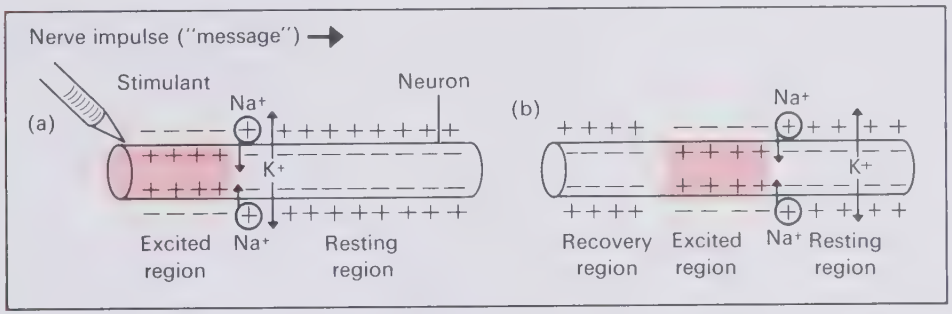


Figure 1-11. How messages travel. In (a), part of a neuron has been stimulated. This results in sodium ions, Na^+, entering the cell while potassium ions, K^+, leave. This exchange moves along the neuron, as is shown by (b). Some of the negatively-charged ions involved are the chloride ions, Cl^-.

This impulse has been measured by microscopic electrodes implanted in the skin and connected to an oscilloscope. When the body is resting, this device reads 70 millivolts. The speed of this wave is about 50 metres per second. The impulse or wave can travel through an individual thirty times per second. These nerve cells can each carry 2500 bits of information—stimuli—per second. That's quite a busy communications system!

The electrical nerve impulse is carried to the ends of the dendrite, those short, free projections off this cell body. From here on, one gets the *chemical* effects of the process. A chemical called *acetylcholine* picks up the electrical message and carries it across the gap (*synapse*) to connecting neurons. Another chemical transmitter found in the body is noradrenaline, and there are probably more such chemicals which have not yet been discovered.

Once the message has been put into action, acetylcholine must be "extinguished." The body has a mechanism to "shut off" the impulse. This is an enzyme called *cholinesterase*. An enzyme is a substance produced by living cells. It can speed up chemical reactions without the enzyme molecule being used up; that is, enzymes are *catalysts*. This enzyme can shut off the impulse in two-thousandths of a second.

The stimulus starts in specialized cells, shown in Figure 1-12. These cells are sensitive to touch, cold, warmth, and pressure, and are found throughout the surface of the body. There are also specialized taste cells

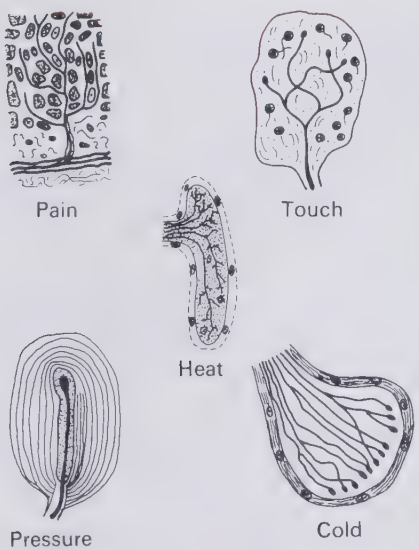


Figure 1-12. Five kinds of specialized cells (sensing devices) found in your skin.

in the tongue. Your fingers, too, are covered with sensing devices. So, for example, if you put your finger on a hot stove, the heat triggers the temperature sensor. A message travels through the neurons, acetylcholine bridges the gap, and the message is received in the muscles. The muscles contract (you jump!), cholinesterase is secreted, acetylcholine is broken down, the information is cut off, and your muscles relax. You then treat your burnt finger. How much of this process did you voluntarily control?

Experiment 1.1
Where are your taste "buds"?

Materials:

(a) Watch glass or other small container
(b) Salt solution (2.5 M 10 per cent—10 g of salt in about 90 cm^3 of water)
(c) Applicators (toothpicks with small ball of cotton wrapped around one end, or "Q-Tips")
(d) Waste jar
(e) Beakers filled with water
(f) Sucrose solution (5 per cent—0.15 M)
(g) Acetic acid solution (1 per cent—0.15 M, or lemon juice)
(h) Quinine sulphate solution (0.1 per cent—0.0013 M)

Method: Work in groups.

(1) Make a copy of Figure 1-13 and label it "Salt."
(2) Dip an applicator into the salt solution, drain excess solution from the applicator and touch the applicator to the tongue of your partner at the point marked 1 in Figure 1-13.
(3) At point 1 in your drawing, place a minus sign (–) if your partner does not taste salt, a plus sign (+) if he senses a mild taste of salt, and a double plus sign (++) if he senses a strong taste of salt. As soon as you have recorded the sensation, touch the applicator to the tongue at point 2. Record your partner's sensations, using the appropriate symbol. Continue until sensations have been recorded at all 5 points on the tongue.
(4) Throw away the applicator. Your partner should now thoroughly rinse his mouth with water. Pour out the solution from the watch glass. Rinse the glass thoroughly and repeat the procedure with each of the other solutions (the "sweet" sucrose, the "sour" acid, and the "bitter" quinine).
(5) Compare your results with those of your classmates. What parts of your tongue contain which kind of specialized taste cells?

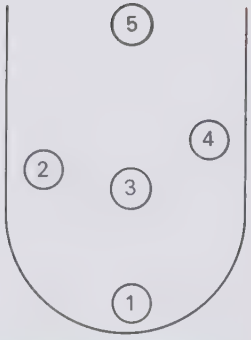


Figure 1-13. Mapping your tongue.

You can repeat this experiment with different concentrations of salt and sugar solutions, for example 0.001, 0.005, 0.01, 0.05, 0.1, and 0.5 per cent. How sensitive is your tongue? Can you taste all concentrations of the solutions? Also, you may repeat these experiments holding your nose

tightly and sipping solutions of orange juice, milk, onion juice, vinegar, sugar, and dill-pickle juice. Are you able to identify what you are tasting?

Figure 1-14 shows the five main divisions of the brain and spinal cord. Together they make up the central nervous system (CNS). The *sympathetic* ("fight or flight" system) and *para-sympathetic* nervous systems function automatically. The *somatic* system is voluntary, giving the body more control over its operations.

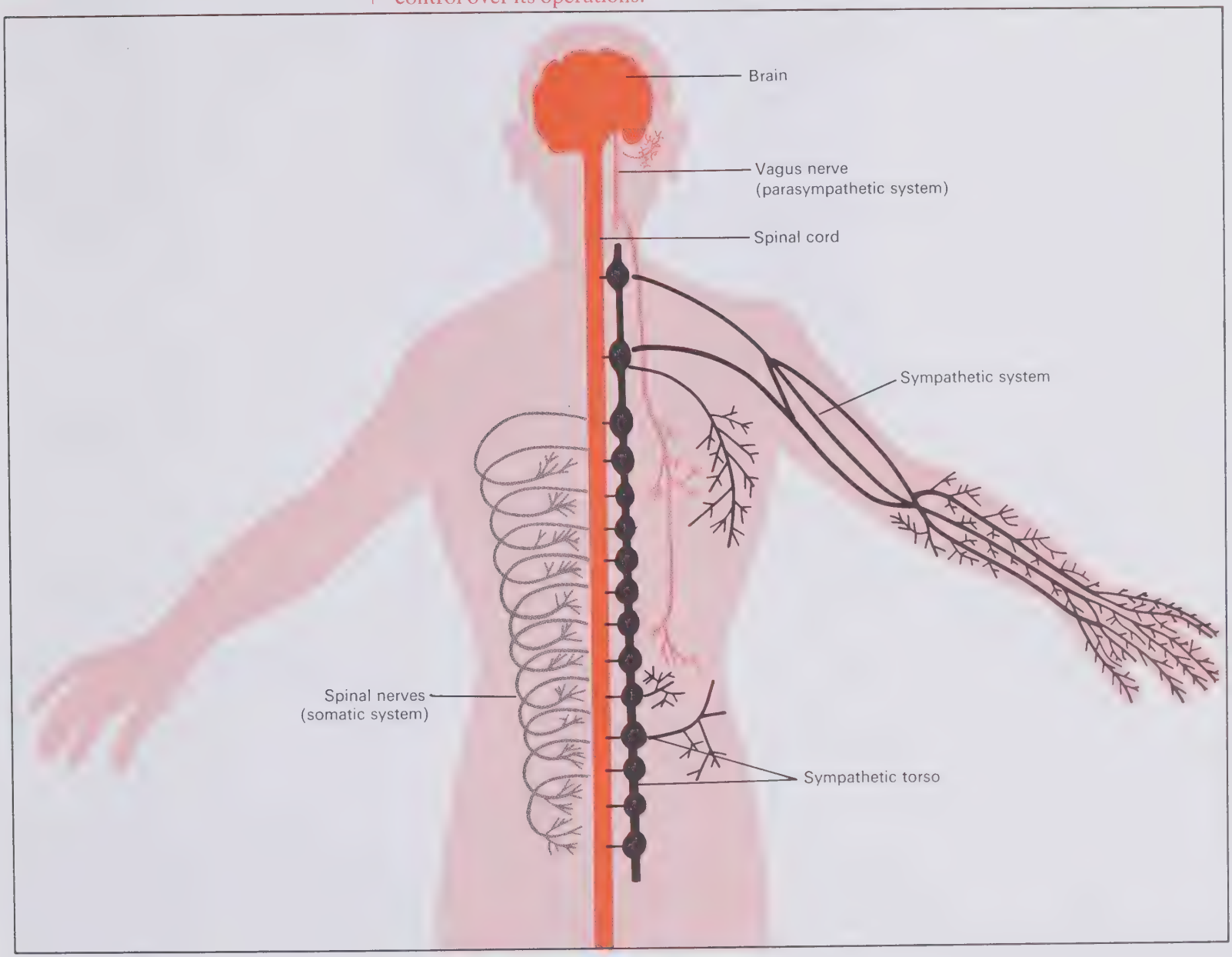


Figure 1-14. Branching of the central nervous system. Shown are the brain, spinal cord, and the sympathetic, para-sympathetic, and somatic branches. This very simplified, partial diagram shows the different branches serving the body.

Experiment 1.2
How fast can you react?

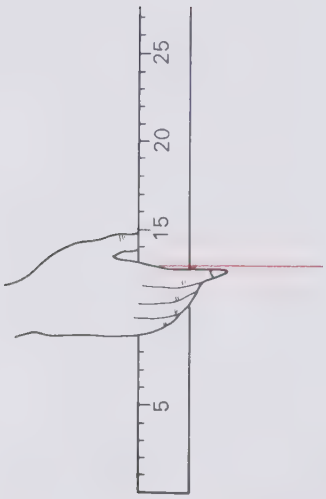


Figure 1-15. How quickly can you grasp the falling ruler?

Materials: Ruler or metre stick.

Method:

(1) Have your partner rest his forearm on the edge of a table with his hand projecting over the edge. His thumb and index finger should be about 3 cm apart.
(2) Hold a ruler by one end, with the lower (zero centimetre) end even with the tops of your partner's thumb and finger.
(3) Drop the ruler. Your partner tries to catch it between his thumb and index finger without moving his hand. Record the point on the ruler where he grasps it. (See the line in Figure 1-15.) Repeat and record several trials. Calculate the average point.

Switch with your partner so he is the observer and recorder. Compare your results with those of your classmates and analyse the class data. For example, compare your average point with the lowest and highest values in the class. What is the difference (if any) between your first and last trial values? How does this difference compare with differences in the class?

Experiment 1.3
Effect of decision-making on reaction time

Materials: A watch with a second hand, deck of cards.

Method:

(1) Have your partner deal a full deck of cards into one pile as rapidly as possible. Record the time needed. Repeat this several times.
(2) Have your partner repeat the experiment, this time separating the red and black cards into two piles. Record the time. Do this several times.
(3) Exchange roles with your partner, so that he is the observer and recorder.
Decision-making time = time to separate red from black cards – time to simply deal the cards
(4) Repeat (1) to (3) above, this time separating the diamonds, hearts, clubs, and spade cards into four piles. Compare your decision-making time for separating red from black cards with that for separating the diamonds, hearts, clubs, and spade cards. Again, analyse the class data.

There are many factors and molecules that may affect your reaction time and your ability to make decisions.

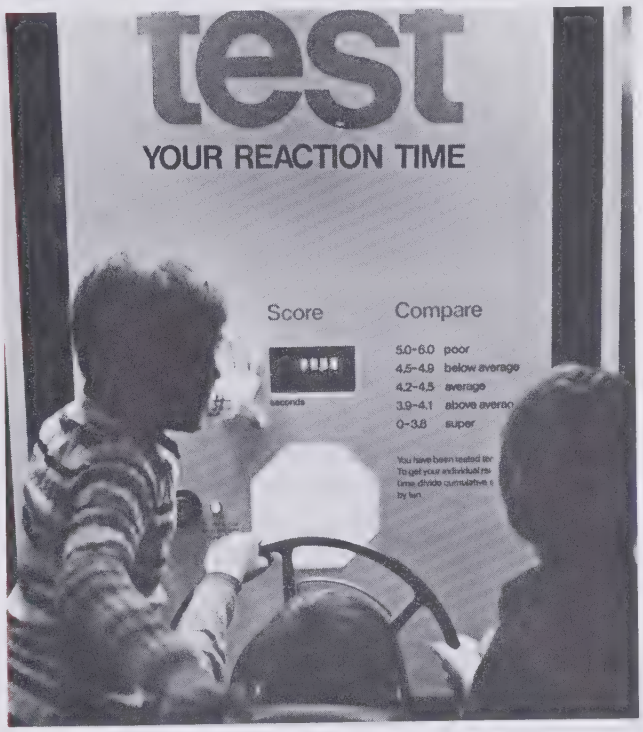


Figure 1-16. Here is a machine on which you can test your reaction time behind the wheel of a car.

Action of molecules on man

Now that you know a little about the human body (that is, you know some physiology), you can investigate how different molecules act when they enter the body. Many molecules you will study have been made by man himself in efforts to relieve suffering and disease, and to maintain a healthy body. For example, molecules may:

—alter the neuron so that Na^+ ions will be more difficult to exchange with K^+ ions;

—alter the passage of messages along the neuron;

—block acetylcholine;

—increase acetylcholine;

—interfere with the production of cholinesterase.

Ask yourself some questions:

What effects does any molecule have on the body?

What are some of the molecules man uses to keep healthy?

What are food additives?

How much of a medicine is needed for the best results?

What is the effect of two or more medicines entering the body at the same time?

As you proceed through this booklet you will gain further information that will allow you to answer these questions intelligently, and hopefully to pose other questions about physical fitness.

Classification of molecules

Man and nature have produced a variety of molecules that act on the body. Table 1-2 lists some of these molecules. "Nitro"?! Yes, the nitroglycerin referred to in Table 1-2 is the same molecule as is used in explosives. Why doesn't someone who takes nitroglycerin tablets explode?

Table 1-2 USEFUL MOLECULES FOR THE BODY

Function of molecule	Examples
Germ-killers (antibiotics). (See Figure 2-5.)	Penicillin, tetracycline, sulphonamides (Chapter 2)
Strong pain killers	Opium, morphine (Chapter 3)
Effects on blood circulation	Nitroglycerin, digitalis
Treatment of wounds	Hydrogen peroxide, iodine compounds, potassium permanganate
Action on respiratory system	Ephedrine
Stimulants for "fight or flight"	Methamphetamine, adrenaline (Chapter 4)
Paralyzing agents, for anaesthesia	Tubocurarine
Kidney medicines: diuretics	Water, chlorthiazide
Body hormones (Figure 1-17)	Cortisone, insulin
Vitamins	Vitamins A, B, C, D, E, K (Chapter 5)
To reduce sensations: anaesthetics	General: ether, chloroform; local: cocaine, procaine
To reduce excitement and produce sleep: sedatives, hypnotics	Barbiturates (Chapter 7), bromides, methaqualone
To alter behaviour	Tranquillizers: chlorpromazine; mood modifiers: cannabis, LSD, mescaline (Chapter 8)
Mild pain-relievers: analgesics; fever-reducers: antipyretics	Codeine, acetylsalicylic acid (ASA) (Chapter 9)
Anti-allergics: antihistamine	Diphenhydramine, tripelennamine (Chapter 10)
Central nervous system stimulants	Caffeine (Chapter 3)
To reduce cell division	Chlorambucil, 5-fluorouracil (anti-cancer drugs)
Body parasite- (lice) and worm-killers	Piperazine, carbon tetrachloride
Diagnostic chemicals	Barium sulphate, radioactive isotopes

Figure 1-17. The co-discoverers of insulin, Frederick Banting and Charles Best, with the first dog whose diabetes was controlled by insulin. See Table 1-2.

2

Antibiotics: "the wonder drugs"

Antibiotics are truly "wonder drugs"; their use in treating such bacterial diseases as pneumonia and tuberculosis (TB) has saved more lives than all the wars of man's recorded history have killed.

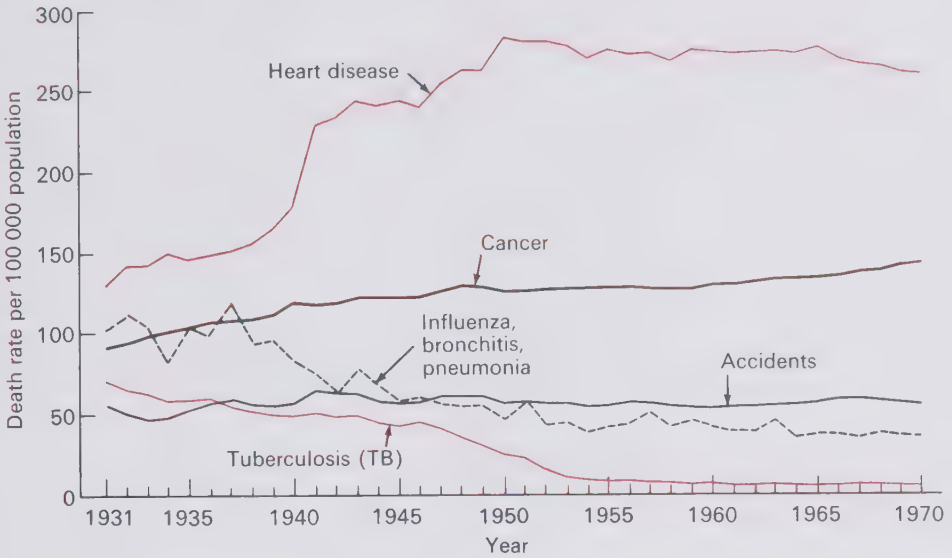


Figure 2-1. The "wonder of drugs" is shown by this graph of Canadian deaths from 1931 to 1970. During this period, research failed to produce molecules that could conquer heart disease. During the same time, the death rate from bacterial diseases such as tuberculosis (TB) steadily fell, thanks to effective antibiotics.

● *Experiment 2.1 Finding and growing bacteria*

How many types of germs (micro-organisms, bacteria) can you find? What do they need to grow?

Materials:

(a) *Nutrient* medium (glucose, peptone, beef or chicken bouillon cubes, ammonium sulphate, potassium di-hydrogen phosphate, calcium chloride, magnesium sulphate, agar, water)
(b) Petri dishes
(c) Cotton swabs
(d) 400 cm^3 or 600 cm^3 beaker
(e) Microscope
(f) Microscope slides

Method: It might be best to work in groups for efficient team work. Always keep your petri dishes closed. Your teacher will dispose of all the germ colonies at the end of your experiment.

(1) Take the mass of the following ingredients for your nutrient medium.

Glucose	4.00 g	$CaCl_2.2H_2O$	0.03 g
Peptone	0.50 g	$MgSO_4.7H_2O$	0.05 g
Beef or chicken soup cubes	0.30 g	Agar	0.15 g
$(NH_4)_2SO_4$	0.60 g	Distilled water	100.0 cm^3
KH_2PO_4	0.20 g		

(2) While one or two group members find the mass of these ingredients, the other group members should begin to boil about 110 cm^3 of distilled water, and mark 10 petri dishes with their names.
(3) Dissolve each ingredient in hot water. Bring to a boil for 5 minutes and remove the source of heat.
(4) Add some of the nutrient medium to each clean, dried petri dish. Allow the medium to cool and solidify.
(5) Using cotton swabs, obtain samples from areas around the room that might contain germs. First, touch these areas with a swab, then carefully stroke the swab backwards and forwards across the solidified medium. You could add objects to some of the petri dishes, for instance chewed up gum, a penny or a small sample of your lunch. Label all dishes with their contents.
(6) Store your dishes under different conditions for 24 to 48 hours.

Group 1	In a refrigerator	Group 4	On a window ledge
Group 2	In an oven at 80°C	Group 5	In complete darkness
Group 3	In an oven at 37°C	Group 6	Under a bright light

(7) Make observations over the 48-hour period. You can obtain a germ colony count by using a marker to divide the top of your dish into quarters (as shown in Figure 2-2). Count the colonies in one such quarter and multiply this number by four. Compare and contrast your observations with those of other groups. You will need your results for Experiment 2.2.

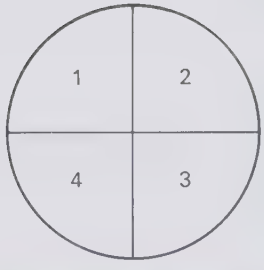


Figure 2-2. How to divide your petri dish for a germ colony count.

What would happen if you altered the kind of nutrient? For instance, you could omit or double the quantity of certain ingredients, use tap water instead of distilled water, and so on. What ingredients favour or slow down growth? Also, use a wire loop to take samples from the germ colonies, place them on microscope slides, and observe the micro-organisms under a microscope.

Experiment 2.2 Antibiotics, antiseptics and micro-organisms

Materials: In addition to the materials used in Experiment 2.1, your teacher may obtain 1 cm discs containing antibiotics. Also, you may prepare *antiseptic* (germicide) discs as follows.

(a) Filter paper
(b) Scissors
(c) Tweezers
(d) Paper towels
(e) Watch glasses or dishes
(f) Dettol, Lysol, iodine, mercurochrome, rubbing alcohol, Listerine, and other mouthwashes or other antiseptics (germicides)

Method:

(1) Bring samples of antiseptics from home.
(2) Cut circles (discs) of 1 cm diameter from a piece of filter paper.
(3) Pour a small sample of the antiseptics you brought from home onto watch glasses. Label each dish with its content.
(4) Using tweezers, dip your filter paper discs into the antiseptics.
(5) Repeat procedures (1) through (7) of Experiment 2.1 using the ingredients and conditions that gave the most growth of germs. Before storing the dishes, lift the discs from the solutions, allow the liquid to drip off and blot lightly on dry towels. Place the discs on the medium in the petri dish. You could put 4 or 5 discs in one dish. Record the positions of the antiseptics on each disc.

Compare the effects of each of the antibiotics and antiseptics on the micro-organisms. Which "germ fighter" is the most effective? Which is least effective in controlling the growth of germs?

There are many parts of Experiment 2.2 that may give rise to experimental errors. For example, such an experiment should be done in a sterile (germ-free) room. Your results should be taken more for their qualitative value.

Experiment 2.3 Are there bacteria in milk?

Although milk is the most nearly "perfect" food (see page 37), it is also an excellent medium for the growth of bacteria.

Materials:

(a) Milk samples
(b) Test tubes
(c) Methylene blue solution
(d) Cotton
(e) Water bath (600 cm^3 beaker half-filled with water)
(f) Thermometer

Method:

(1) Bring to class 3 or 4 samples of milk from different sources, for example: fresh unopened milk, milk opened and in the refrigerator for 1, 2 or more days, powdered milk, canned milk, and so on.
(2) Fill separate test tubes one-third full with each of the samples. Label each tube with its contents, and add 1 cm^3 (20 drops) of methylene blue solution to each tube.
(3) Label another test tube, one-third full of distilled water, and 1 cm^3 of methylene blue solution. This is the "control."
(4) Plug each tube with sterile (bacteria-free) cotton and then place the tubes into a water bath kept at 37°C.
(5) In a table similar to Table 2-1, record how long it takes to decolourize each sample (until the colour of normal milk returns).

(6) Examine each of the milk samples and "control" over a 1- or 2-day period, and rate the samples according to bacterial contamination (time to decolourize methylene blue). See Table 2-2.

Table 2-1 RATING OF MILK SAMPLES

Contents of test tube	Time to decolourize methylene blue	Rating
1.		
2.		
3.		
4.		

Table 2-2 TIME NEEDED TO DECOLOURIZE METHYLENE BLUE

Less than 15 min	Highly contaminated	6—8 hr	Good
15 min—2 hr	Poor	More than 8 hr	Excellent
2—6 hr	Fair		

When bacteria are growing, they use up oxygen. You can see this reduction of oxygen by using methylene blue, which turns colourless in the absence of oxygen. So, if the number of growing bacteria is high, they will use up oxygen rapidly and the methylene blue solution will, in turn, quickly lose its colour.

Which milk sample rated the highest in bacterial contamination? Which rated the lowest? What happened to the "control" test tube? What factors appear to lead to contamination of milk? What are the chemical ingredients of milk—what *is* milk?

Effects of "wonder drugs"

What effect did the antibiotics have on the germs? Is there a significant difference in the number and size of germ colonies in the presence of the antibiotics? Compare and contrast the effects of the different antibiotics on germ growth.

There are thousands more bacteria and fungi besides those you found in Experiment 2.1. Each antibiotic can control the growth of only a certain few types of germs. In 1935, over 20 000 Canadians died from infectious diseases such as tuberculosis (TB) and pneumonia caused by germs. In 1972, the death toll from this group of disease-bearing germs dropped to 7000.

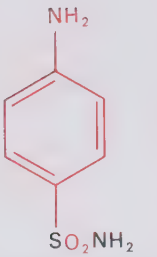
Since 1935, three major groups of antibotics have been discovered —the sulphas, penicillins, and tetracyclines.

The sulphas (sulphonamides)

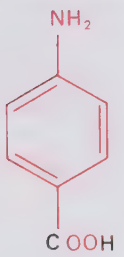
The discovery of the first sulphonamide, sulphanilamide, in 1935 marked the beginning of a major revolution in the techniques of combatting disease. Over 3300 sulphonamides have been prepared, but only a few have been accepted for medicinal use. How sulpha molecules work in the body has been well researched and is the best understood of the antibiotics.

Consider a *disease-causing* bacterial cell containing an enzyme. An enzyme is a molecule in the body that helps the proper functioning of the body chemistry. It is a "biological catalyst." Think of it as a "lock." To grow, the harmful bacterial cell needs a molecule called para-aminobenzoic acid (PABA). This is the "key" that fits into the bacterial enzyme "lock" to start cell growth. (See Figure 2-3.) You can call it the "lock-key" mechanism or "goodness of fit." Note from Figure 2-4 the similarities between the sulphanilamide and PABA molecule. What would happen if the sulpha medicine instead of PABA contacted the enzyme?

In fact, the sulpha is also a "key," one made by man. It fights PABA for the bacterial enzyme. If sufficient sulpha is present, it will block or antagonize PABA. Thus, without PABA the harmful bacterial cell dies. *PABA* opens a door for *cell growth*, while *sulpha* opens a door for *cell death* (Figure 2-5).



Sulphanilamide

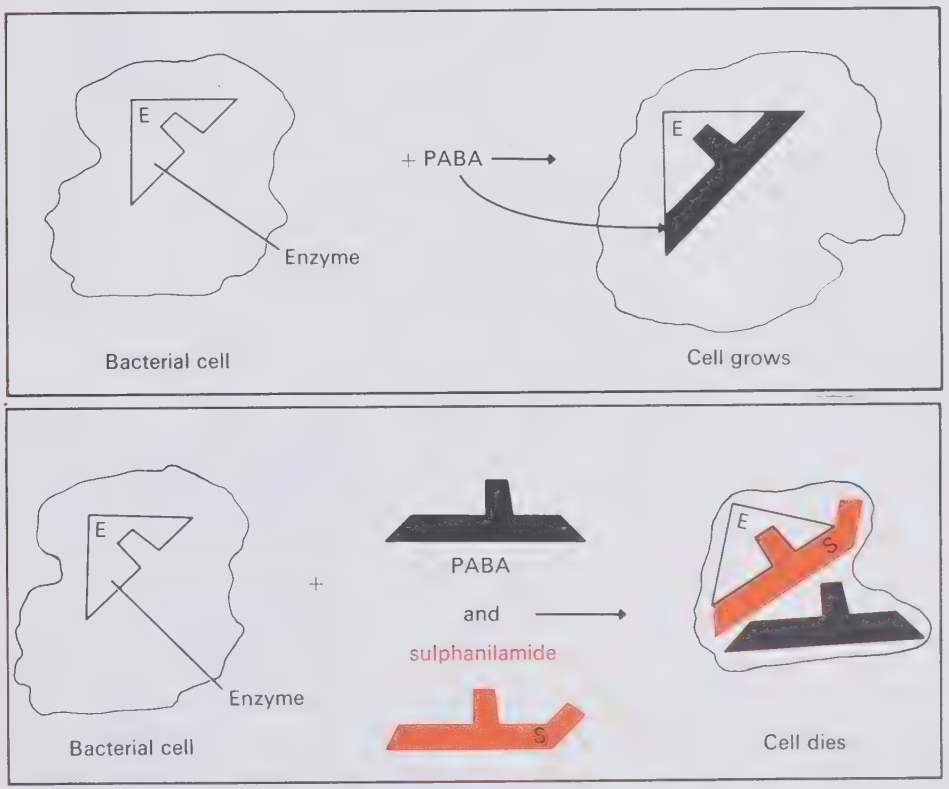


PABA

Figure 2-3 (upper right). This diagram shows the growth of a cell due to the presence of para-aminobenzoic acid (PABA).

Figure 2-4 (above). Note the striking similarity of these two molecules!

Figure 2-5 (right). This drawing shows the competition between PABA and sulphanilamide for the enzyme. Because of the "good fit" of the sulphanilamide molecule into the enzyme, PABA cannot join with the enzyme, and the cell dies.



From this example you now know a basic concept for the action of certain molecules in the body. Where the enzyme is the lock, the sulpha molecule is the man-made key. Thanks to the "good fit" of this lock and key, a door is opened. In medical books this is referred to as "biological antagonism."

Other useful sulphonamides or sulpha molecules include: sulphacetamide, sulphaguanidine, sulphadiazine, sulphamerazine, and sulphamethazine.

A problem with taking sulpha molecules is the possible "*side effect*" of crystal production in the urine. This results in crystals blocking the urinary passage. To prevent this, patients are told to drink lots of water to dissolve the crystals and keep the sulpha in solution.

With desirable molecular activity there is often also undesirable biological activity (side effects) produced by the molecule. A doctor will judge the desirable activity against its side effects, as in the use of sulphas. With sulphas, the benefits from curing disease seem to outweigh the rare side effects.

Penicillin

In 1929, a British bacteriologist, Alexander Fleming, as a result of an accidental spill in his laboratory, noticed that bacteria died in the presence of a destructive chemical he called "penicillin." Penicillin is a chemical compound produced from a living cell that restricts the growth of some micro-organisms.

The ® in Figure 2-6 stands for a particular group of atoms. There

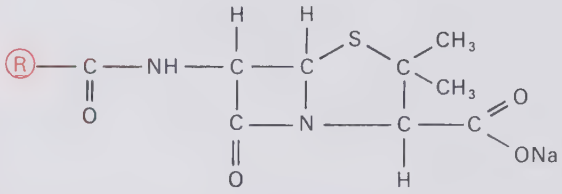


Figure 2-6. The sodium salt of penicillin. The natural penicillins differ in the structure of the (R) group of atoms.

are dozens of such groups; each results in a different form of penicillin. Figure 2-7 shows some of these natural pencillins.

There are many other semi-synthetic penicillins. Pure penicillin is a white, crystalline solid. The crystal may reflect light in interesting ways, and it is possible to photograph penicillin and other crystals through a microscope. The photomicrograph on the cover of this booklet is of penicillin crystals.

When water is added to a penicillin preparation, the solution begins to deteriorate after a few days, even in a refrigerator. For this reason, penicillin solutions obtained from your drug store are dated to tell you how long the molecule will be fully active. After this "expiry date" the penicillin molecule begins to lose its power against bacteria in your body. If you have not

According to one Canadian study, 76 per cent of people taking medicines use them incorrectly.

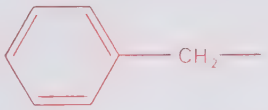
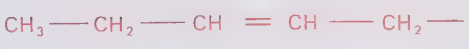
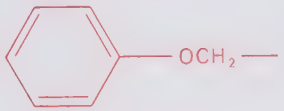
Penicillin	(R) group
Penicillin G	
Penicillin F	
Penicillin V	

Figure 2-7. Three natural penicillins.

used up the penicillin by this date, you should empty the contents of the bottle into the toilet, and flush.

Another interesting yet troublesome property of the penicillin molecule is that acids, for example the stomach acids which digest your food, break it down. Penicillin should be taken when the acid content in the stomach is at its lowest level. This is usually when the stomach is empty.

The mechanism of the action of penicillin is not completely known. Researchers, however, have noticed that bacteria in the presence of penicillin take in less oxygen gas than normal.

Tetracycline

In 1953, the Heyden Chemical Corporation announced the isolation of a molecule named "tetracycline" found in a soil sample from Texas. Tetracycline is a yellow, odourless, crystalline powder, which darkens on exposure to strong sunlight. The tetracycline molecule, also, can be affected by certain chemicals. Calcium weakens it. Why should you not drink milk with tetracycline preparations?

The search for newer and better antibiotics continues. Some bacteria develop a resistance to antibiotics. Researchers in laboratories around the world are producing different molecules to fight disease and permit you to live a longer, healthier life. It is important that this search should continue so that antibiotics can be developed faster than bacteria become resistant to the ones we already have.

3

Medicines from plants

Figure 3-1. Turkish farmers have grown poppies for centuries. They have found uses for a number of poppy by-products, for instance poppy oil which is suitable for cooking purposes. In 1972 the Turkish government banned the growth of the opium poppy after the United States government subsidized farmers against losses. The ban was an attempt to cut out what the States claimed was a major source of illegal heroin and other by-products. Two results of this move were increased unemployment in Turkey and a shortage of opium for medicinal purposes. Turkey therefore decided to once more allow farmers to grow the opium poppy. This time, however, in a continuing attempt to prevent illegal trafficking in heroin, the government imposed on its opium farmers a process known as "poppy-strawing." Instead of extracting the opium gum by slicing the poppy—the farmer in the photograph is holding poppies cut in this way—the farmer has to allow the poppy pod to dry out on the plant. He then hands over the entire plant to the government, which processes it into morphine, codeine and other pain-killing drugs that help to meet legitimate world needs.

This Turkish farmer is holding a "bouquet" of poppies, which for centuries have been a major source of opium, one of the first *drugs* known to man. Opium is an *alkaloid*. The uses of alkaloids are numerous: to relieve pain, stimulate the central nervous system, open breathing passages, reduce fever, open the pupil of the eye, and reduce blood pressure, to mention a few.

Alkaloids, the active drugs obtained from many plants, have been isolated by various investigators until today they number hundreds. Among the main properties of alkaloids are the following.

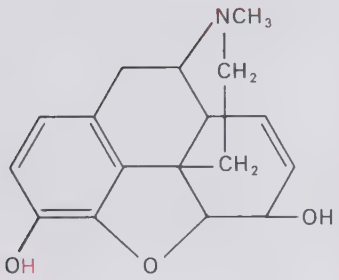
(1) In addition to carbon and hydrogen, they all contain nitrogen and, generally, oxygen atoms. The nitrogen gives the *alkali*-like properties (see page 49) to *alka*loids.
(2) Most alkaloids are active in the body, some being extremely poisonous.
(3) They are generally white.
(4) They are either insoluble or sparingly soluble in water.
(5) Nearly all alkaloids change the direction of a beam of light rays in solution.

Structures and activities of opium alkaloids

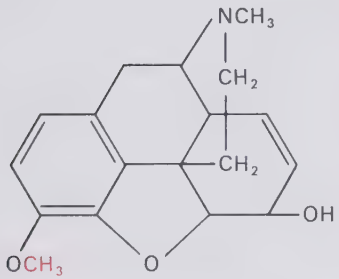
Opium is the air-dried substance obtained after cutting the unripe top of the *Papaver somniferum* plant. Although the poppy has been grown for many centuries as a medicinal drug, not until Sertürner's discovery in 1817 was it known that opium contained what are now called alkaloids. There are at least twenty-five alkaloids in various kinds of opium.

Opium owes its chief medical effects to the presence of morphine. Here is one of the many examples in pharmaceutical chemistry where comparing structure and activity is interesting. Note in Figure 3-2 the striking molecular similarities of three alkaloids, morphine, codeine, and heroin.

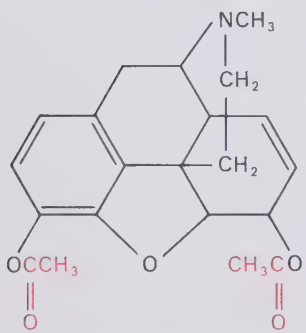
All three alkaloids are most important drugs. (See Table 3-1.) When wisely used, they can do great good; when unwisely taken, they can do severe harm. Few drugs relieve pain so well.



Morphine molecule



Codeine (methylmorphine) molecule



Heroin (diacetylmorphine) molecule

Figure 3-2. Molecular similarities of three alkaloids.

Table 3-1 COMPARISON OF USES AND DOSES OF THREE ALKALOIDS

	Morphine	Codeine	Heroin
Uses	Relief of pain, sedation	Relief of pain, sedation, *anti-tussive* (against cough)	Relief of pain, sedation, anti-tussive
Dose	5—10 mg	30 mg	3 mg

Codeine may be called a weakened morphine. It is less likely to cause nausea and vomiting than morphine. Many products, such as "AC and C" tablets and cough preparations, contain codeine. Heroin is a synthetic alkaloid; it is artificially made from morphine using a specific chemical process. Morphine also slows down respiration, and an overdose can kill. For these reasons, codeine is more widely used to relieve pain. These chemicals are all addictive. Repeated usage can cause *physiological dependency*.

The ideal pain killer would be a molecule that relieves pain without producing the side effects of nausea, vomiting, and decreased breathing, and it should not cause addiction. Such a molecule has not yet been discovered. The search for the "ideal" molecule presents one of the great challenges to modern chemistry and medicine.

Caffeine

• *Experiment 3.1*
Extraction of caffeine

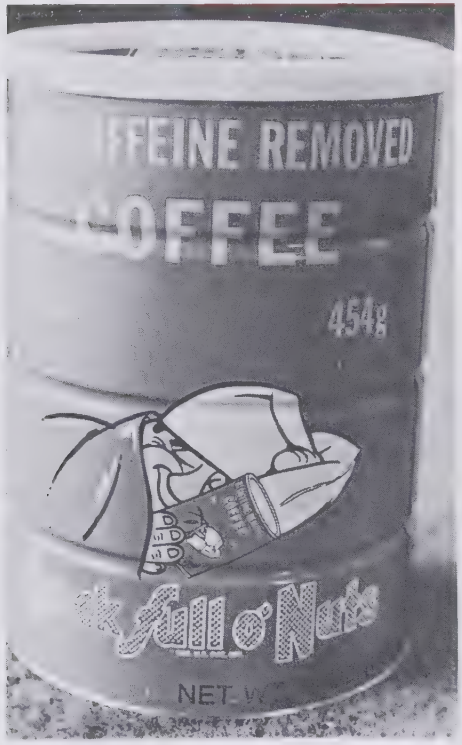


Figure 3-3. Ninety-eight per cent of the caffeine has been removed.

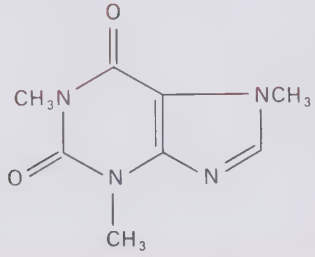


Figure 3-4. The caffeine molecule—a central nervous system stimulant.

"Glory be, it's caffeine-free!" Figure 3-3 shows the caffeine content of a brand of coffee. Other brands of coffee and tea contain larger quantities of caffeine.

How much caffeine is there in a tea bag or a spoonful of coffee?

Materials:

(a) Coffee grounds, instant coffee, freeze-dried coffee, tea leaves, or instant tea
(b) 400 cm^3 beaker
(c) Distilled water
(d) Ring stand and clamps
(e) Filtering apparatus (Buchner funnel with suction is best)
(f) Lead acetate
(g) Separatory funnel
(h) Dichloromethane*
(i) Benzene*
(j) Petroleum ether*
(k) Porcelain evaporating dish
(l) Large watch glass
(m) Heating element

*These chemicals should be used with adequate ventilation, preferably a fume hood.

Method:

(1) Find the mass of one of the following: 100 g of coffee grounds; 15 g of either freeze-dried or instant coffee; 5 g of tea leaves; 1 g of instant tea.
(2) Place one of the above in a 400 cm^3 beaker and add 250 cm^3 of distilled water. Boil the solution or mixture for 15 minutes and then filter the solution.
(3) Add 25 cm^3 of a 10 per cent lead acetate solution, boil for 5 minutes, and filter.
(4) Place the filtered solution in a 400 cm^3 separatory funnel and add 30 cm^3 of dichloromethane. Shake well, allow the layers to separate, and then remove and save the bottom dichloromethane layer. The separatory funnel should be inverted and the stopcock opened to expel vapours during the shaking process.
(5) Repeat the procedure of adding 30 cm^3 of dichloromethane to the upper aqueous layer. Shake and combine the bottom layer with the other dichloromethane extract.
(6) Distil the combined extracts to dryness over a steam bath. *Do not use a direct open flame.*
(7) Dissolve the remaining crude caffeine in 10 cm^3 of dichloromethane and evaporate it to dryness on a steam bath.
(8) Dissolve the crude caffeine in 5 cm^3 of hot benzene and add slowly 10 cm^3 of cool, high-boiling petroleum ether. Filter the white crystals.
(9) Repeat the benzene-petroleum ether procedure.
(10) Determine the melting point. The expected melting point of caffeine is 238°C.

You can remove caffeine from your favourite soft drink by using the following procedure. In a 400 cm^3 beaker, place 250 cm^3 of bottled soft drink or 50 cm^3 of a cola syrup diluted with 50 cm^3 of distilled water. Add 10 cm^3 of concentrated ammonium hydroxide. Mix the liquid well for several minutes, but do not shake it vigorously or an emulsion will result. The solution can be used to extract caffeine according to procedures (4) to (10) above.

Tea, coffee, or a soft drink—most contain caffeine. Compare the amounts of caffeine in the various sources and discuss such questions as, "Is coffee more likely to keep you awake at night than tea?"

Caffeine is contained in coffee beans, which are the seeds of Coffea arabica. It is used in headache remedies and to counteract barbiturate poisoning. See page 40.

Another alkaloid is cocaine, which is made from leaves of Erythroxylon coca, a shrub which grows in the Andes mountains of South America. Cocaine is used as a local anaesthetic for operations on the nose and throat.

Coffea arabica

Erythroxylon coca

Action of caffeine

Caffeine stimulates the heart, increases blood flow through the coronary arteries, relaxes the smooth muscle of the bronchi, and is a diuretic (increases the rate of urine formation). In man, caffeine stimulates the central nervous system (CNS), the part of our system which includes the brain and spinal cord. In particular, that part associated with mental functions is stimulated; ideas become clearer, thought flows more easily and rapidly, and fatigue and drowsiness decrease. However, *connected* thought becomes *more difficult*, for impressions follow each other so rapidly that the attention is distorted. More and more effort is needed to limit oneself to a single thought. Many people become restless and suffer from sleeplessness when they drink coffee or tea late at night.

"AC and C" tablets contain *A*cetylsalicylic acid, *C*affeine, and *C*odeine.

Large quantities of caffeine often cause headaches. In some lower animals, the injection of large quantities of caffeine produces symptoms resembling those of strychnine poisoning, such as convulsions. *Tolerance* (the situation in which a larger dose of a drug is needed to get the ordinary reaction) results from prolonged use of coffee or tea. Tea contains 1 to 5 per cent caffeine and coffee that is not caffeine-free 1 to 1.5 per cent.

Your library will have more information on the physiological effects of caffeine on man and other animals. Factors such as respiration rate, activity level, and eating and sleeping habits might be interesting areas to pursue.

Nicotine

Nicotine is obtained from the *Nicotiana tobacum* plant. It is a poisonous, oily liquid. It has an unpleasant tobacco-like odour, a burning taste, and a strongly alkaline reaction. Some of these properties are most evident to the non-smoker, and are often ignored by the addicted smoker.

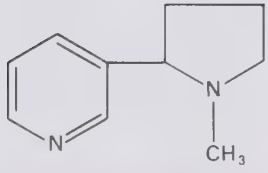


Figure 3-5. The nicotine molecule. Nicotine is used as an insecticide and for delousing poultry. Gram for gram, nicotine is more poisonous than coniine, the poison of the hemlock plant which Socrates drank.

● *Experiment 3.2 Destructive distillation of a cigarette*

What is produced during the burning of a cigarette? Although this experiment does not directly parallel what happens when you smoke a cigarette, it is intended to demonstrate the substances that can be obtained from a cigarette in the absence of air.

Materials:

(a) Two test tubes (one hard, thick-walled pyrex)
(b) Ring stand with clamp
(c) One-hole rubber stopper
(d) Two-hole rubber stopper
(e) 400 cm^3 beaker
(f) Glass tubing
(g) Non-filtered cigarette

Method:

(1) Place a cigarette in a hard, thick-walled pyrex test tube and take the mass of the cigarette and the test tube.
(2) Arrange the apparatus shown in Figure 3-6. Hold the Bunsen burner by its base and heat the test tube with a moderate flame until there is no further observable action. Note any changes taking place in the horizontal and vertical test tubes. Try to light any gases produced at the jet, and describe the flame.
(3) When the horizontal test tube is cool, take the mass of it and its contents.
(4) Shake some of the residue onto a piece of paper. Press it with your finger. How does it differ from the original cigarette?

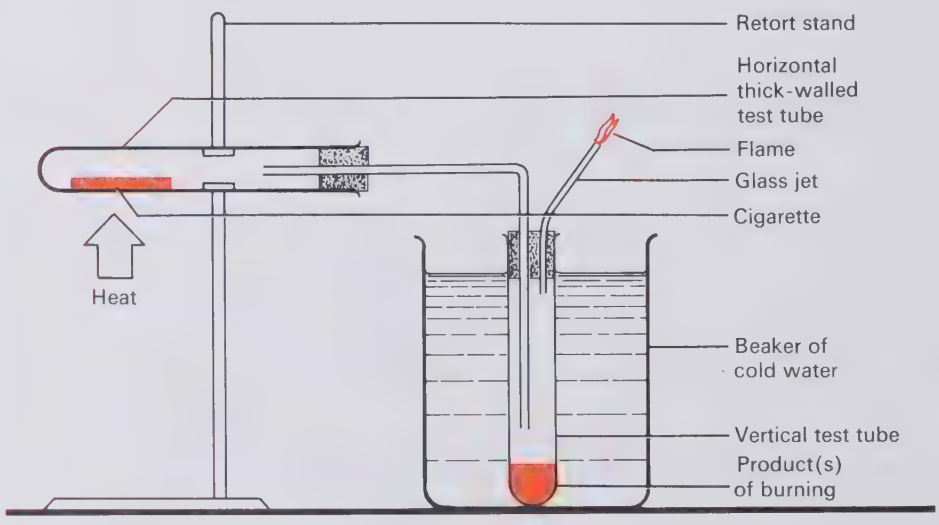
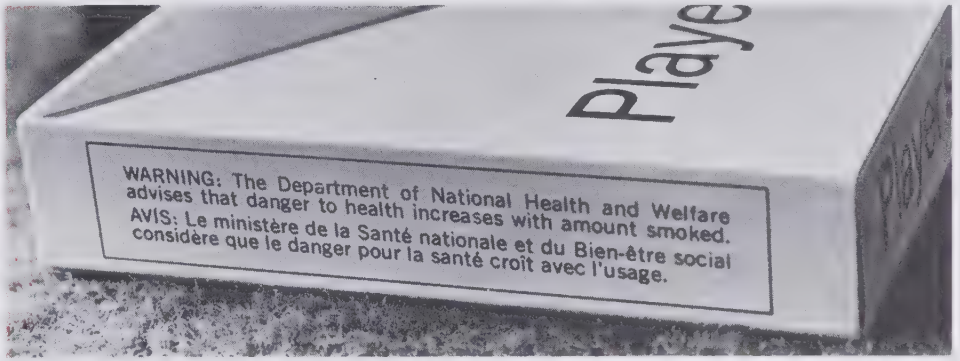


Figure 3-6. Destructive distillation of a cigarette. Besides the tobacco, paper tube and filter, cigarettes may contain small amounts of invert sugar or glycerin. These are added to the tobacco as top dressings or to help retention of moisture. Some brands also contain flavourings such as menthol.

How do you explain the observations you noted in the horizontal and vertical test tubes? What gases are produced at the jet? What substance(s) is/are left as a residue in the horizontal test tube?

Why is this process called "destructive distillation"? Define destructive distillation.


Player
WARNING: The Department of National Health and Welfare advises that danger to health increases with amount smoked.
AVIS: Le ministère de la Santé nationale et du Bien-être social considère que le danger pour la santé croît avec l'usage.

• *Experiment 3.3 Making and operating a smoking machine*

What happens when you smoke a cigarette?

Materials:

(a) Plastic squeeze container for dishwashing liquid
(b) Ball-point pen barrel
(c) Cotton
(d) Cigarettes

Method:

(1) Rinse the container thoroughly. Make an opening in the cap of the container large enough to fit the pen barrel into the cap. Place the pen barrel into the opening and seal it with cement or clay if necessary. (See Figure 3-7.)

(2) Insert a loosely-packed cotton ball into the pen barrel. Find the mass of a cigarette and insert it into the open end of the pen barrel. Press firmly on the plastic container to force air out before lighting the cigarette, then start slow and regular pumping (breathing in—breathing out) action. Note the time.

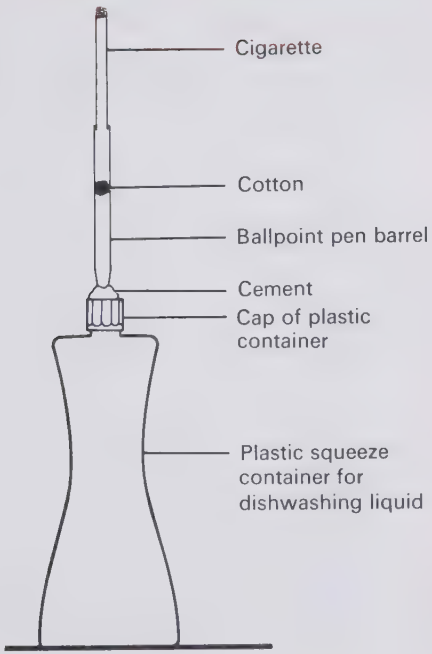
(3) Collect all the ash from the burning cigarette and take the mass of the cigarette and ash after about three-quarters of the cigarette has been burned.

(4) Withdraw the cotton from the pen barrel and note the changes in the cigarette, cotton, plastic container, and pen barrel.

(5) Note the time required for: (a) the burning of three-quarters of the cigarette; and (b) the odour of the cigarette to disappear.

(6) Calculate the difference in mass of the cigarette before lighting it, and the cigarette and ash at the end of the experiment.

Figure 3-7. A smoking machine.



Women who smoke when pregnant tend to have smaller babies than non-smoking mothers, and are more likely to give birth prematurely. They also have a greater percentage of still-births, and death among their new-born babies is more common.

You could use your ingenuity to construct a different smoking machine. Comment on the design of your machine and how it relates to a person smoking a cigarette. What substances are found in the cigarette ash, on the cotton, in the plastic container, and in the pen barrel?

Assume that a person smokes three-quarters of a cigarette and that he ingests 5 per cent of the products of the burning. Calculate how many grams of the products the person would inhale if he smoked a twenty-cigarette package in a day.

You can vary this experiment in several ways by removing the cotton, using a filter-tipped cigarette, comparing residues left on the cotton from different brands of cigarette, and by using a cigar.

Action of nicotine

If you ingest 2 mg of nicotine, your pulse rate and blood pressure increase. The breathing system is first stimulated and then depressed. Secretions increase temporarily, then are depressed. Nicotine causes powerful contractions in the stomach wall, resulting in nausea, vomiting, and emptying of the bowel.

When small quantities of nicotine are ingested repeatedly, the body soon gains a certain tolerance. A familiar example of this is seen in smokers. Most are depressed and feel or are sick when they first use tobacco. After a while no such symptoms occur.

The abuse of tobacco may result in dimness of vision (especially for colours), headaches, palpitations and irregularity of the heart, and various forms of cancer. A final note: spectators who smoke at a football game, thinking the cigarette will warm them, are in fact reducing their body temperature!

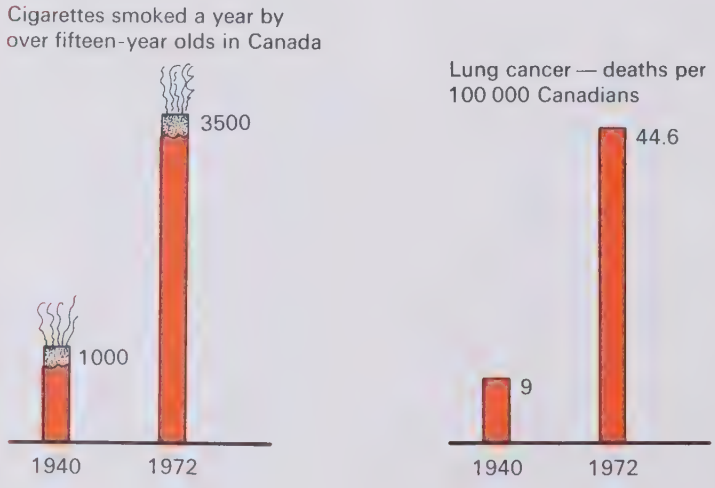


Figure 3-8. These Canadian statistics may suggest a relationship between lung cancer and the number of cigarettes smoked.

4

"Fight or flight" molecules

Figure 1-10 shows your spinal cord with its numerous chains linking some of the body's organs. This system in your body can react to a dangerous situation in the following way. If you meet up with an attacker, your body will then secrete a molecule called adrenaline (it is also known as epinephrine), which:

—widens the iris of the eye to let in more light;
—increases the rate of your heart beat and strengthens your heart;
—widens your breathing passage;
—slows down the digestion of foods ;
—closes passages leading from the kidneys;
—stimulates the sweat glands; and
—constricts the blood vessels so that the rate of blood flow increases.

Figure 4-1 shows the "fight or flight" (sympathetic) system.

As you can see, the action of this molecule can make you run quickly or fight strongly. After such an emergency, the body usually relaxes. There is a release of tension. The nerves leading from the central nervous system to the eye carry impulses that reduce the opening of the eye. The "fight or flight" reaction of your body is rapid and prepares you instantly to meet an emergency.

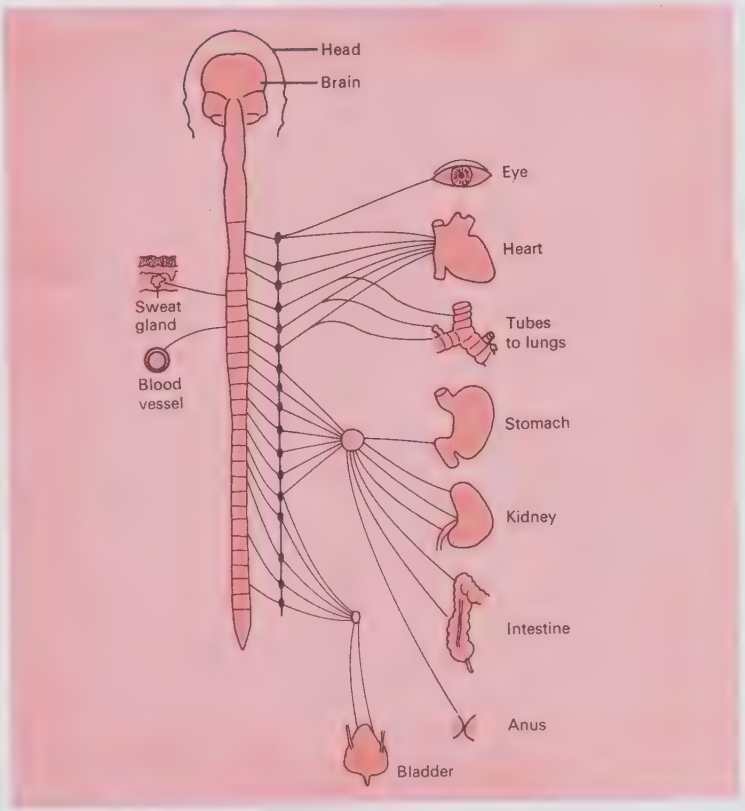


Figure 4-1. The sympathetic nervous system. This system prepares the body for "fight or flight."

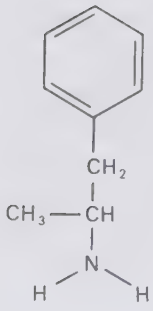


Figure 4-2 (above left). The amphetamine molecule.

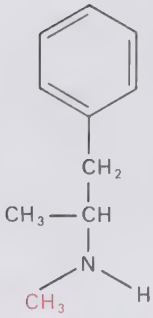


Figure 4-3 (above right). The methamphetamine molecule.

Amphetamine (known as "pep pills," "wake-ups," or "bennies") is a man-made molecule whose actions on the body resemble those of adrenaline. Amphetamine was once used to reduce the appetite of overweight people. With repeated usage, the body requires larger amounts of the molecule and one can become addicted. Abusers increase their dosage gradually, resulting in excitability, talkativeness, shaking of the hands, enlarged pupils of the eyes, and heavy perspiration. The only medical use for amphetamine today is in the treatment of narcolepsy, a disease in which the patient has an overwhelming need for sleep.

Methamphetamine (known as "speed" or "meth") is chemically related to amphetamine (see Figure 4-3) but it has more central nervous system activity. Some abusers "shoot" speed and eventually build up to doses many times the medicinal dose. An additional danger to those who "mainline" or shoot methamphetamine is the possibility of infection from the use of non-sterile injection equipment.

"Speed" in sport?

This is the skeletal chemical structure of steroids. There are slight variations to this structure in different steroids.

—Drugs in the Olympics—doped horses—footballers and drugs.

Drugs and sport: the two seem to be linked more and more these days. Will all victorious athletes, like racehorses, soon have to take tests to make sure that their successes are not due in part to drugs?

It is believed that some athletes in the 1972 Olympic Games took short-lived drugs, which boosted their performance and then disappeared without trace. Besides "speed," a caffeine and nicotinamide (niacinamide) mixture has also been used. Other athletes are known to take "anabolic *steroids*," which greatly strengthen muscles. These "builder-uppers" are believed to be favoured by weightlifters, shotputters, and athletes in other events where strength is very important. The British Sports Council—which thinks it has found a way of testing for the presence of anabolic steroids—states:

> **Their use is believed to have been a factor in raising performance in many Olympic and world championship sports to the point that in some events competitors not using steroids stood little chance of winning.**

The test for detecting anabolic steroids has been welcomed by Lord Killanin, President of the International Olympic Committee. He said: "This is good news . . . our aim has been to defeat the creation of artificial man or woman." The Council's Chairman, Dr. Roger Bannister, had this to say: "Sports competitors who take steroids are not only cheating, they may be risking serious damage to their health. There is evidence that steroids taken in large doses can cause liver damage and a reduction in fertility." (Does Dr. Bannister's name ring a bell? He was the first man to run a mile in under four minutes, back in 1954.)

On the left are statistics showing how some world athletics records have increased since 1952. Throwing and training techniques have greatly improved over the years.

World records

	1952	1974
Discus		
F. Gordien (USA)	**56.97 m**	
R. Bruch (Sweden)		**67.58 m**
Hammer		
J. Csermak (Hungary)	**60.34 m**	
A. Bondarchuk (USSR)		**75.20 m**
Shot		
J.E. Fuchs (USA)	**17.9 m**	
A. Feuerbach (USA)		**21.82 m**

5 Vitamins and minerals

Vitamins are complex molecules needed for animals—including man—to live normally. Vitamins are effective in relatively small amounts. They do not supply energy themselves, but are essential for regulating our body's processes. Table 5-1 gives a recommended daily requirement for some of the vitamins.

• *Project 5.1* *Vitamins and your daily diet*

What is in multivitamin tablets? Must you take them? How many tablets a day do you need?

Method:

(1) Purchase or bring from home a multivitamin preparation.
(2) List in chart form the contents of the vitamins in your preparation.

Table 5-1 RECOMMENDED DAILY DIETARY ALLOWANCES OF SOME VITAMINS

Age (yr)	Mass (kg)	Ht (cm)	A act (IU)	E act (IU)	Ascorbic acid (mg)	Ribo-flavin (mg)	Thia-mine (mg)	B_{12} (μg)
Infants								
0–1/6	4	55	1500	5	35	0.4	0.2	1.0
1/6–1/2	7	63	1500	5	35	0.5	0.4	1.5
1/2–1	9	72	1500	5	35	0.6	0.5	2.0
Children								
1–2	12	81	2000	10	40	0.6	0.6	2.0
2–3	14	91	2000	10	40	0.7	0.6	2.5
3–4	16	100	2500	10	40	0.8	0.7	3.0
4–6	19	110	2500	10	40	0.9	0.8	4.0
6–8	23	121	3500	15	40	1.1	1.0	4.0
8–10	28	131	3500	15	40	1.2	1.1	5.0
Males								
10–12	35	140	4500	20	40	1.3	1.3	5.0
12–14	43	151	5000	20	45	1.4	1.4	5.0
14–18	59	170	5000	25	55	1.5	1.5	5.0
Over 18	67	175	5000	30	60	1.6	1.4	5.0
Females								
10–12	35	142	4500	20	40	1.3	1.1	5.0
12–14	44	154	5000	20	45	1.4	1.2	5.0
14–16	52	157	5000	25	50	1.4	1.2	5.0
16–18	54	160	5000	25	50	1.5	1.2	5.0
Over 18	58	163	5000	25	55	1.5	1.0	5.0
Pregnancy			6000	30	60	1.8	0.1	8.0

World Health Organization

Don't throw away your cooking water. Make it into a gravy—it contains many vitamins.

(3) Using Table 5-1, write the recommended daily dietary allowances for your age beside each vitamin in your list.
(4) In a third column of your table, compare the multivitamin preparations with the recommended daily dietary allowances.
(5) Repeat the comparison for another age group. You may select other members of your family, or friends.
(6) Check other books to find the vitamin content of the foods you eat, and add a fourth column to your chart, "Vitamin content in my daily diet."

Do you need a multivitamin preparation? You could exchange vitamin preparations with other members in your class and repeat the project. What are your conclusions about the different preparations?

The identification, characterization, and manufacture of vitamins during the 1930s, like antibiotics, was another exciting chapter in the history of biological and organic chemistry.

Properties of vitamins

In pure form, *vitamin A* is a pale yellow oil, soluble in fat solvents. It fluoresces when exposed to ultra-violet light. The molecule is necessary for normal vision in dim light.

Vitamin D includes more than one chemical substance. Pure vitamin D_3 appears as white, odourless crystals that are soluble in fat solvents, such as ether, alcohol, or chloroform, but are insoluble in water. The main job of vitamin D is to increase the absorption of calcium and phosphorus from the intestinal tract. Calcium and phosphorus are essential for bone and tooth development. Cod liver oil is a valued source of vitamins A and D.

Vitamin E represents a group of molecules called "tocopherols." They are rather thick oils at room temperature, and are soluble in fat solvents. Vitamin E is essential for normal reproduction in many animal species.

Vitamin K (see Figure 5-1) is part of your blood-clotting mechanism. It is a light yellow solid, soluble in fat solvents, like Vitamins A, D, and E. It melts at 54°C. Vitamin K is found in green plants, such as alfalfa and

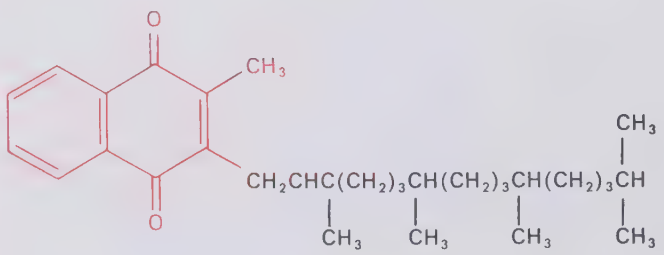


Figure 5-1. The vitamin K molecule. In addition to your own diet, an important source of vitamin K is the normal bacteria of the intestinal tract.

spinach. Menadione (see Figure 5-2), a man-made molecule with vitamin K activity, is a bright yellow crystalline powder, nearly odourless. It melts between 105°C and 107°C.

Figure 5-2 (right). Menadione is man-made vitamin K. Vitamin K is essential for blood clotting.

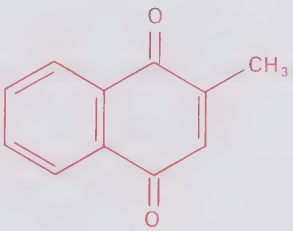
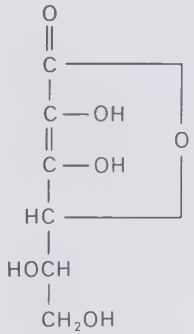


Figure 5-3 (far right). The least stable of the vitamins, vitamin C is fairly stable in acid solutions but unstable in basic solutions. (Refer to page 50.) Much ascorbic acid is destroyed by cooking when the pH is basic. There are also losses of the vitamin when it is stored.



Vitamin C (ascorbic acid) is a white or slightly yellow, odourless crystal or powder, which on exposure to light gradually darkens. When dry, it is reasonably stable in air, but in solution it rapidly deteriorates in the presence of air. (1 g dissolves in about 3 cm^3 of water.) Loss of vitamin C may occur in fresh fruits and vegetables stored for a long time. Your daily requirements for vitamin C can be obtained from drinking about 120 cm^3 (one-half glass) of fresh lemon or orange juice. The Nobel Prize winner, Linus Pauling, has written that massive daily doses of vitamin C (1000 to 2000 mg) might help to prevent the common cold. There has been much controversy about his suggestion.

Experiment 5.1 Vitamin C content of orange juice

How much of an orange is vitamin C? How does the vitamin C content of an orange compare with lemon juice, fresh orange juice, and canned, frozen, or powdered orange juice?

Materials:

(a) Orange squeezer
(b) 100 cm^3 graduated cylinder
(c) Burette
(d) Funnel
(e) Erlenmeyer flask
(f) Glass tube
(g) Glacial (concentrated) acetic acid
(h) Sodium dichloroindophenol
(i) Cheesecloth
(j) Orange and knife

The acetic acid can cause severe burns on skin and clothing. Handle it with care.

Method:

(1) Cut an orange in half and squeeze out the juice. Record the volume of fresh juice. Filter the juice through the cheesecloth in a

funnel. Wash any residue on the squeezer through the filter. When the juice has filtered through, wash the filter and allow the wash water to drip through into the filtrate. Use a total of 10 cm^3 of water for all your washings.

(2) Pour the filtrate into a graduated cylinder and record the volume.

(3) Dilute the juice with twice its volume of water. Mix well and put the diluted juice into a burette. Fill the burette tip and record the reading on the burette.

(4) Dissolve 5.0 mg of sodium dichloroindophenol in 10 cm^3 of warm water. Add 1 or 2 drops of glacial (concentrated) acetic acid, which should change the colour from blue to wine red. Add the dilute orange juice from the burette, drop by drop, until the wine-red solution is just decolourized. Note the burette reading and calculate the volume of orange juice required to decolourize the solution. The solution is just decolourized by 1 mg of vitamin C.

From the volume of orange juice used and the total volume of juice in the orange, calculate the vitamin C content of the whole fresh orange. Here is an example.

Volume filtered fresh orange juice (half orange), plus washings	25.0 cm^3
Volume diluted orange juice	50.0 cm^3
Initial burette reading (tip filled)	0.50 cm^3
Final burette reading after decolourizing solution	2.50 cm^3
Volume fresh orange juice in filtrate (25.0 cm^3 − 10 cm^3 wash water)	15.0 cm^3
Volume diluted orange juice used to decolourize solution (2.50 − 0.50 cm^3)	2.00 cm^3

Since 50.0 cm^3 of diluted juice contains 15.0 cm^3 of actual orange juice, 2.00 cm^3 of dilute juice contains

$$\frac{15.0\ cm^3}{50.0\ cm^3} \times 2.00\ cm^3 = 0.60\ cm^3$$

of actual orange juice. Therefore 0.60 cm^3 of actual fresh orange juice decolourized the solution and 0.60 cm^3 of actual juice contains 1 mg of vitamin C.

1.0 cm^3 of actual juice contains

$$\frac{1\ mg}{0.60\ cm^3} \times 1.0\ cm^3 \text{ of vitamin C}$$

15.0 cm^3 of actual juice contains

$$\frac{1\ mg}{0.60\ cm^3} \times 15.0\ cm^3 = 25.0\ mg \text{ of vitamin C}$$

Since 15.0 cm^3 was obtained from half an orange, the whole fresh orange contains

$$2 \times 25.0 \text{ mg} = 50.0 \text{ mg of vitamin C}$$

These sample calculations have been simplified. Your data will probably contain numbers like 24.7 cm^3, 49.8 cm^3, 1.43 cm^3, and so on.

The Canadian Association of Consumers reports that 120 cm^3 of fresh, canned, and frozen orange juice contain 71 mg, 50 mg, and 42 mg of vitamin C respectively.

You can repeat the experiment using canned, frozen, and powdered orange juice. Compare their vitamin C content. Also, you can experiment with different fruits and juices and compare the vitamin C content and prices of the products.

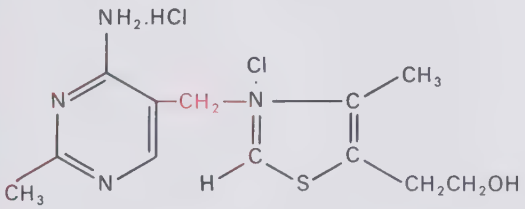


Figure 5-4. The thiamine molecule (vitamin B_1). This vitamin is also known as thiamine hydrochloride.

Figure 5-5. Part of a crystal of vitamin B_{12}, as seen under a microscope.

Thiamine (vitamin B_1) was first isolated from rice bran in 1926 by B. C. P. Jansen and W. F. Donath. It is essential for the normal functioning of the nervous system. R. R. Williams in 1935 first established its structure. It is a white, crystalline substance and very soluble in water. The molecule is made up of two rings connected by a "—CH_2-bridge." It is at the bridge in the molecule that splitting may occur. Thiamine is comparatively stable in acid solutions and resists heat. However, in neutral or alkaline solutions it is rapidly destroyed by heat. Thus, during the baking of bread, from 10 to 20 per cent of the thiamine is lost, while in biscuits that contain enough soda to give a pH greater than 7, more than half of the thiamine may be destroyed during baking.

Riboflavin, or vitamin B_2, is widely distributed in both plants and animals, as an essential part of all living cells. It is quite stable in food processing except where there is excessive exposure to light. Bottled milk, for example, may lose as much as half its riboflavin content if left to stand in sunlight for several hours.

Cyanocobalamine or vitamin B_{12} (Figure 5-5) is unique in that it is the only vitamin containing an essential mineral element, cobalt.

So you can see that each vitamin has characteristic properties. Check references at the end of this booklet for information about what can happen when you do not get enough vitamins.

Minerals

In addition to vitamins, minerals (elements) are necessary for normal growth. Table 5-2 lists some of the essential elements, their effects on the body and some excellent food sources from which they may be obtained. Here, too, you can investigate the effects of a deficiency of these elements on the body.

Table 5-2 SOME ESSENTIAL ELEMENTS FOR THE BODY

Element	Some biological effects	Excellent sources
Calcium, Ca	Building of bones and teeth	Asparagus, beans, cauliflower, cheese, cream, egg yolk, milk
Chlorine, Cl	Enzyme activities; formation of hydrochloric acid in stomach	Bread, buttermilk, cabbage, cheese, clams, eggs, ham (cured), sauerkraut, table salt
Cobalt, Co	Normal appetite and growth	Liver, sea food, sweetbreads
Copper, Cu	Formation of haemoglobin; aids tissue respiration	Bran, cocoa, liver, mushrooms, oysters, peas, pecans, shrimp
Iron, Fe		
Iodine, I	Regulation of metabolism	Broccoli, fish, iodized table salt, oysters, shrimp
Potassium, K	Normal growth; muscle function	Beans, bran, molasses, olives, parsnips, potatoes, spinach, oranges
Sodium, Na	Protection against excessive loss of water	Beef, bread, cheese, oysters, spinach, table salt, wheat germ

Crystals

In this booklet there have been several references to crystals. The photograph on the cover of this booklet is of penicillin crystals—beautiful, isn't it! If you want to take colour photographs of crystals, instructions are given in *Chemistry of Photography* in this series. You can even grow your own crystals. Here's how.

● *Experiment 5.2 Growing crystals*

Materials:

(a) 250 cm^3 beakers
(b) Watch glasses to cover beakers
(c) 250 cm^3 wide-mouth bottles, with corks
(d) Stirring rod
(e) Bunsen burner
(f) Gauze
(g) Alum ($AlK(SO_4)_2.12H_2O$)
(h) Rochelle salt (KNa tartrate)
(i) Chrome alum
(j) Sodium bromate
(k) Thermometer
(l) Thumb tack
(m) Filter paper
(n) Thread

Method:

(1) In a 250 cm^3 beaker, heat 100 cm^3 of water to about 50°C. Dissolve 20 g of common alum in the hot water.

Transfer the warm solution to the bottle through a funnel fitted with a plug of gauze. Label your bottle with its contents, your name, and the date. Cork the bottle and set it aside until the next period.

(2) At the beginning of the second period, examine the bottle of alum solution to check whether any crystals have grown. Should any have formed in the bottle, transfer all its contents to a beaker and repeat step (1).

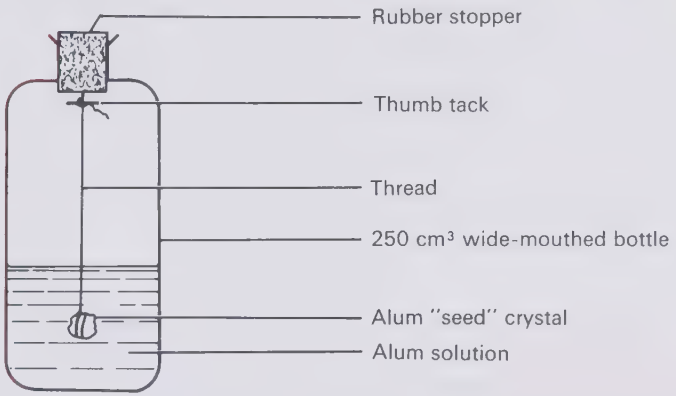


Figure 5-6. Apparatus for Experiment 5.2.

(3) Select a small crystal of alum about 2 mm across. With a knot, fasten it to a length of thread. Using a thumb tack, fasten the thread to the middle of the smaller end of a cork. Adjust the length of thread so that when the cork is fitted into the 250 cm^3 bottle, the crystal will be suspended in the solution about 2 cm from the bottom of the bottle. Practise making these adjustments on an empty 250 cm^3 bottle.

(4) Very carefully lower the small crystal at the end of its thread into the alum solution in the bottle. Insert the cork and leave the bottle and contents undisturbed for a few days, at a room temperature between 21 and 25°C. Make observations during these days.

(5) When your crystal has grown to 1 to 2 cm across, remove it from the solution, dry it with filter paper, and examine it carefully. Make a sketch of your crystal, and try to describe its shape. Compare your crystal with those grown by other students in the class.

(6) You may wish to grow other crystals. Here are three you could try:

Rochelle salt, 130 g per 100 cm^3 of hot water;
Chrome alum, 60 g per 100 cm^3 of hot water;
Sodium bromate, 50 g per 100 cm^3 of hot water.

6 Food additives

The following list of ingredients appears on a can of a soft drink:

> Carbonated water, sugar, colour, phosphoric acid, sodium saccharin, caffeine, citric acid, flavours.

This list is on a box of cookies:

> Enriched flour, sugar, coconut oil, shortening, corn flour, cocoa, invert syrup, leavening agent, salt, skim milk powder, malt flour, artificial flavours and colours, lecithin.

Quite a mouthful!

• *Project 6.1 Investigating contents of household foods*

What do you eat?

> (1) List the ingredients of at least 10 food products found in your home.
> (2) Compare your list with at least 2 other lists of your classmates. Record those ingredients which appear in more than one food.

Why are these ingredients present in foods?

Food additives were used before 2300 B.C., when man preserved fish with wood smoke and added spices to food (often to hide the smell and taste of rotting meat!). A "food additive" is any substance added to a product for a certain purpose during production, processing, storage, or packaging. The term does not include the basic foodstuff itself. There are about 2500 different food additives in use today, many artificially produced. They have more than 40 functions.

The Federal Department of National Health and Welfare in Ottawa regulates the use of food additives. Contact the department for lists and regulations of acceptable food additives.

Some additives have been banned. For example, cyclamate (a sweetening agent) was found to produce disease in rats when they were given large quantities of it. Cyclamate has been removed from the list of acceptable additives, but is available as a "non-caloric sweetener" for people who may not eat sugar.

"Man worth his salt"

We cannot live without salt. Thousands of years ago people found out that, by licking the face of other humans, they could get the salt they needed. (This, by the way, is thought to be the origin of kissing!) Roman soldiers were sometimes paid in salt, which was very useful in preserving food.

Salt is probably the most common additive. It is often used to stimulate taste buds in the tongue (Experiment 1.1); many recipes say "salt according to taste." Table salt bought in the grocery store contains the element iodine (iodized salt). Since the federal government passed a law making

manufacturers include iodine in their salt, goiter (a disease caused by iodine deficiency) has been rarely seen. There are also salt substitutes available for people who may not have salt (people on a sodium-reduced diet).

Experiment 6.1 How much water is there in foods?

Two-thirds of your body is water. How much water is there in your food?

Materials:

(a) Flat-bottomed dish (e.g., top or bottom of a petri dish)
(b) Food samples from home (e.g., raw hamburger, liver, fish, vegetables)
(c) Balance
(d) Oven

Method:

(1) Carefully take the mass of a flat-bottomed dish. Keep a record of your results in a table similar to Table 6-1.

Table 6-1 WATER IN FOODS

	Food samples			
(a) Mass of empty dish				
(b) Mass of dish plus food sample				
Mass of dish plus food after heating for: 1 day				
2 days				
3 days				
4 days				
(c) Final constant mass of dish plus food				
CALCULATIONS (d) Mass of food sample before heating ((b) − (a))				
(e) Mass of food sample after heating ((c) − (a))				
(f) Difference in mass of food sample ((d) − (e))				
(g) Per cent water content in food sample $\left(\frac{(f)}{(d)} \times 100\right)$				

(2) Spread a thin layer of a food sample over it and accurately take the mass of the dish and food.
(3) Place the uncovered dish in an oven or incubator, and keep it at 88°C for several days.
(4) Each day, remove the dish from the oven and find the mass of its contents. Repeat this procedure each day for several days until the mass is constant.
(5) Repeat (1) to (4) above using different types of food.
(6) Calculate the per cent of water content in foods and compare your results with those of your classmates. What foods have the greatest water content? How do your results compare with the amount of water in the body?

The ideal food—mother's milk

Breast milk is the perfect food. The only way it can be made less than the perfect baby food is for the mother to take drugs that pass into her milk. Molecules that have been found in human milk include: alcohol, amphetamines, aspirin, morphine (in trace amounts), heroin, penicillin and other antibiotics, most antihistamines, barbiturates, caffeine, DDT, nicotine, and vitamins.

Women who breast feed their babies and who smoke from ten to twenty cigarettes a day pass along from 0.4 to 0.5 mg of nicotine in each litre of milk. This equals 6 to 7.5 mg of nicotine in the adult. If you read page 24, you can find out how 2 mg of nicotine can affect an adult.

Unbelievable as it may seem, there is little information available on the flow and amounts of most chemicals in breast milk.

The table compares mother's milk with that of a commercially prepared infant formula. This formula is another example of man's attempts to match nature. It is used by mothers who either are not able to, or prefer not to, breast feed their babies.

MOTHER'S MILK, AND A COMMERCIAL FORMULA

	Protein	Fat	Carbohydrate
Human milk ("average")*	7%	51%	42%
Formula	9%	50%	41%

Vitamins, minerals per litre**	Mother's milk*	Formula*
Vitamin A, units	1660	1500
Vitamin D, units	4.0	400.0
Vitamin C, mg	40.0	50.0
Thiamine, mg	0.15	0.4
Riboflavin, mg	0.4	1.0
Niacinamide, mg	1.6	4.0
Pyridoxine, mg	0.1	0.6
Pantothenic acid, mg	1.8	2.0
Vitamin E, units	5.3	5.0
Vitamin B_{12}, mcg	Trace	1.0
Choline, mg	85.0	85.0
Iron, mg	1.4	2.0
Copper, mg	0.37	0.4
Iodine, mcg	65.0	65.0

*Biotin, folic acid, vitamin K, and certain minerals in breast milk were not added to the formula because the milk in the formula supplies ample amounts.

**Normal feeding dilution, 20 calories per 28.41 cm^3.

7

"Goofballs" and "downers"

Barbiturates

Can't sleep? Then take "Snorezze" tablets, the ads tell you. Half the people in North America have difficulty getting to sleep. They have insomnia; they swallow about 200 000 kg of *barbiturate* tablets and capsules every year to help them sleep.

"Barbiturates" is the name of a group of synthetic molecules made from barbituric acid. (See Figure 7-1.) Taken in small doses they reduce excitement, but larger doses make you sleepy. Variations of barbituric acid have been synthesized since 1900 and more than fifty are available on *prescription* from a doctor.

Barbiturates are classified by the length of time the molecules act in the body: "long," "intermediate," "short," and "ultrashort." Figure 7-2 lists some of these variations of barbituric acid.

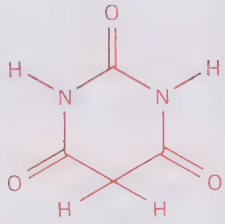


Figure 7-1. Barbituric acid. Barbiturates are among the most frequently used "hypnotics" and "sedatives." They are all variations of the barbituric acid molecule.

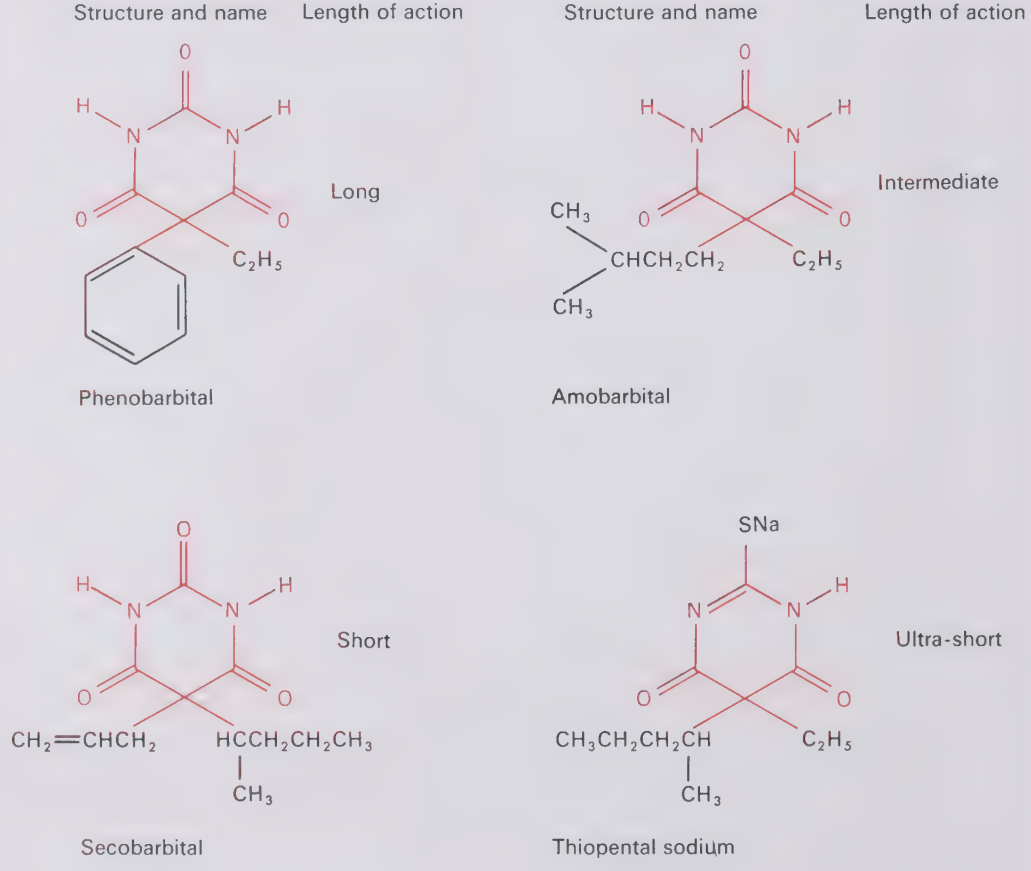


Figure 7-2. Structure-activity relationships of barbiturates.

Project 7.1
Building barbiturate models

What feature is found in all the molecules listed in Figure 7-2? What variations in molecular structure produce the different lengths of action?

Materials:

(a) Cardboard
(b) Scissors
(c) Coloured plasticine
(d) Toothpicks
(e) Pipe cleaners (cut into 2 cm lengths)
(f) Styrofoam spheres
(g) Commercial molecular model kits

Method:

(1) Identify the common molecular feature of the barbiturates. From your materials select one (e.g., styrofoam sphere) to represent this molecular feature.
(2) Using other materials, build up the side groups for the entire molecule. For instance, you could use toothpicks and plasticine of different colours to represent the side groups around the styrofoam.
(3) When you have built a number of barbiturates, try to predict which side group produces what kind of effect in the body. For example, the 2 $—C_2H_5$ groups in barbital are rather small side groups compared to the 2 side groups in thiopental. It seems that in this case the shorter the side groups, the longer the molecule is active in the body. Is there any relationship between the total number of carbon atoms in the side groups and the length of action?

Compare the common side groups of the barbiturates. Suggest why different side groups produce different lengths of action in the body.

Figure 7-3. Building barbiturate molecular models. You can make models that describe the structure of the barbiturates.

Uses and abuses of barbiturates

Barbiturates are used for epilepsy, high blood pressure, and in the treatment and diagnosis of mental disorders. They are used before and during surgery. Under medical supervision, barbiturates are safe and effective.

On the street they are called "goofballs" or "downers." Individually they have a variety of names: "red devils" (secobarbital), "blue heaven" (amobarbital), and "yellow jackets" (pentobarbital). Misuse of barbiturates results in tolerance, *psychological dependence* (habit formation), and physical dependence (addiction). Accidental deaths and suicides from barbiturate poisoning and barbiturate addiction are common.

Alcohol, thalidomide, and other sedatives and hypnotics

In addition to the barbiturates, other agents are useful *sedatives* and *hypnotics*. These include: alcohol (brandy, whisky), bromides (sodium, potassium), glutethimide, methpyrolon, and thalidomide. Thalidomide, introduced as a sedative in the 1960s, was thought to be safer than barbiturates but, when taken by pregnant women it sometimes caused abnormalities in their babies. The search for newer and safer sedatives and hypnotics continues.

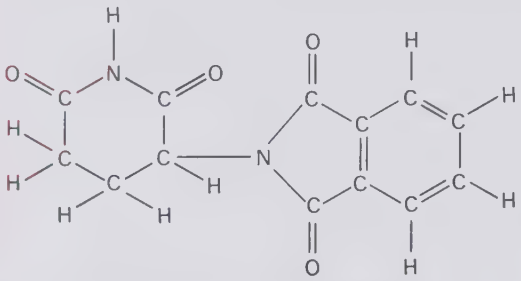


Figure 7-4. The thalidomide molecule.

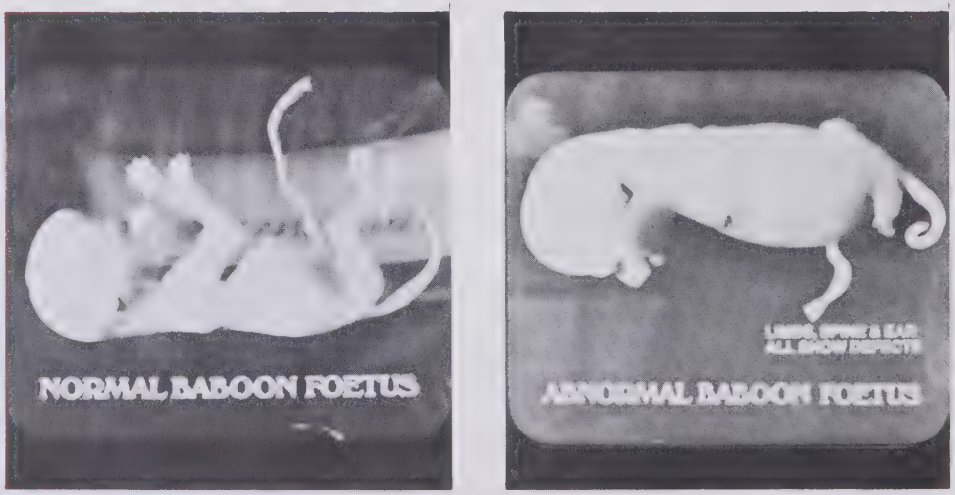


Figure 7-5. Thalidomide affects baboons in the same way as it does humans. The drug, when taken by a pregnant woman, may cause abnormal development of her child. Over 100 children were born with flipper-like arms and legs before the drug was banned.

8

"Moody molecules"

Figure 8-1. Tranquility. This photograph shows a reduction in aggression in the cat when under the effect of the chlordiazepoxide hydrochloride molecule. The molecule does not affect normal reflexes or appetite.

A variety of molecules encourage sleep, calm tension, block sensations, and stimulate imagination. Most act on the nervous system at a point called the synapse, where the tip of a nerve fibre (axon) approaches another nerve. (See Figure 8-2.)

One nerve cell may receive signals from as many as 25 000 axons. Researchers are identifying the chemical reactions which take place at these nerve fibres and are mapping their locations. A world leader in this research is Dr. Wilder Penfield, a brain surgeon with the Montreal Neurological Institute. He has applied electrical stimulation to different parts of the brain and

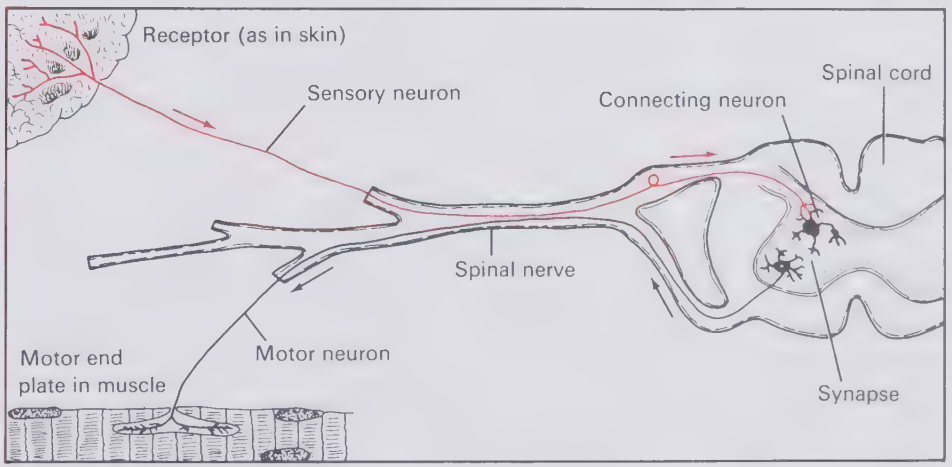


Figure 8-2. Signals from specialized sense cells in the skin travel along a sensory neuron in the spinal cord, then along connecting motor neurons to the muscle. Synapses are the gaps between neurons.

recorded the response of the individual.

Figure 8-3 illustrates some of the "mapped" regions of the brain.

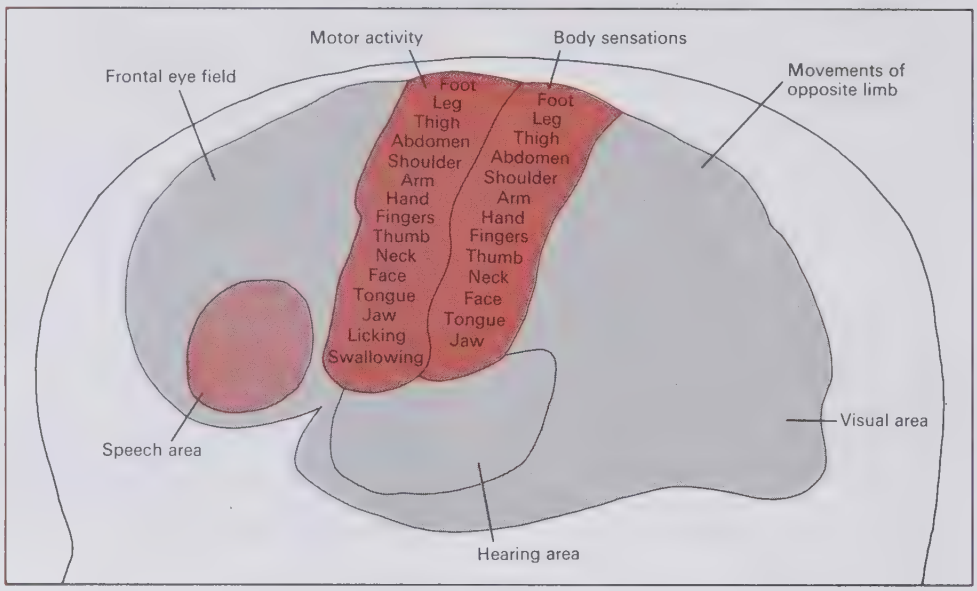


Figure 8-3. A "map" of the brain. This sketch shows that different areas of the brain control certain functions of the body.

Tranquillizers

The term "*tranquillizer*" refers to a large group of molecules introduced since the 1950s. Unlike the barbiturate-type sedatives, tranquillizers relieve tension and anxiety without producing sleep or significantly affecting mental and physical functions. They are divided into two groups, "major" and "minor." Major tranquillizers like chlorpromazine and reserpine are used in severe mental disorders (psychoses). Reserpine, a purified alkaloid first isolated in 1952 from a *Rauwolfia* plant (illustrated in Figure 8-4) is also used to treat high blood pressure. Minor tranquillizers like meprobamate and chlordiazepoxide, are widely used in the treatment of emotional disorders characterized by anxiety and tension. Many are useful as muscle relaxants. Tranquillizers appear to affect brain areas involved with the emotions and instincts for survival in fear, feeding, mating, and the "fight or flight" centre.

Figure 8-4. Reserpine is an alkaloid obtained from the Rauwolfia serpentina shrub, which grows mainly in India. Reserpine was used for centuries as a remedy for insomnia and insanity. Today it is used to combat high blood pressure and mental illness.

"Pep pills, eye openers, or bennies"

Stimulants are molecules that directly stimulate the central nervous system (CNS). A widely known stimulant is caffeine (investigated in Chapter 3), an ingredient of coffee, tea, cola, and other drinks. Synthetic stimulants such as amphetamine, methamphetamine, and other closely related molecules have been abused.

The abuse of these drugs and other chemicals is widespread. Because the body develops a tolerance to amphetamines and many other chemicals, abusers increase their drug dose gradually. These molecules cause excitability, talkativeness, tremor of the hands, enlarged pupils, and heavy perspiration. Continued abuse of amphetamines can cause high blood pressure, abnormal heart rhythms and severe emotional disturbances. To obtain money for their drugs, some addicts steal. The cost to society in money and human lives is high.

Cocaine is an alkaloid found in the leaves of the coca bush of South America. (See page 21.) Cocaine was the first local anaesthetic to be discovered. It is a white crystalline, odourless powder with a bitter taste producing numbness of the tongue. (The word "coca" is often confused with "cocoa." The two are not related. Cacao is the tree from which cocoa and chocolate are obtained.) Stimulation from the cocaine molecule is followed by depression. Overdoses can so depress breathing and heart action that death results. It is not used as a central stimulant in medicine because of its dangerous effects.

"Seeing" sounds, and "hearing" colours

"Trips," dream images, and hallucinations are caused by a group of molecules called *hallucinogenics*, psychotomimetics, or psychedelics. They include mescaline, d-lysergic acid diethylamide (LSD), psilocybin, dimethyltryptamine (DMT), 2,5-dimethoxy-4-methyl-2-methylphenethylamine (DOM or STP) and marihuana (cannabis).

"Grass"

Marihuana comes from the dried flowering tops of the female *Cannabis sativa L.* plant, which is more frequently called "Indian hemp." The plant grows in mild climates throughout the world, especially Mexico, Africa, India, and the Middle East. It also grows in Canada where the term "marihuana" has other names—"hashish," "bhang," "gansa," "pot," "tea," "weed," "grass," and "Mary Jane." Its strength differs from place to place, depending on where and how it is grown, prepared for use and stored. For example, Canadian marihuana is much weaker than the Mexican variety. Although known to man for nearly 5000 years, marihuana is one of the least understood of all natural drugs.

Figure 8-5. Leaves of the marihuana plant.

Traffic in and use of molecules from the cannabis plant is now legally restricted in many countries, including Canada and the United States.

Marihuana fibres have been used to make twine, rope, bags, clothing, and paper. The sterilized seeds are occasionally included in various feed

mixtures, particularly bird seed. Very early in China's history, it was used as a pain-killer during surgery. In India it was used as a *medicine*. In the United States, it was a remedy for corns.

In 1966, the active part of marihuana, tetrahydrocannabinol (THC) was first synthesized in pure form. When smoked, THC appears to enter the bloodstream in about fifteen minutes. It affects the user's mood and thinking. The molecule's effects on the emotions and senses vary widely, depending on the amount and strength of marihuana used and on the social setting in which it is taken. Research is currently being done into the short- and long-term effects of the molecule. It is expected that scientists will soon better understand marihuana and its effects on memory, mood, and perception.

"Acid"

LSD, one of the most talked-about molecules of recent years, fascinates scientists. Not only is it tremendously strong—100 micrograms (not enough to cover the point of a pin) can give a person a trance or "trip"—but its action gives clues to nerve-cell chemistry. The LSD molecule (see Figure 8-6) looks like a major part of a chemical called serotonin (see Figure 8-7). Serotonin may be one of the brain chemicals that transfers signals from an axon tip across a synapse to another cell. This similarity of molecular structure between LSD and serotonin may explain LSD's power.

Figure 8-6 (right). LSD is synthesized from naturally occurring lysergic acid. LSD has very powerful properties for altering behaviour.

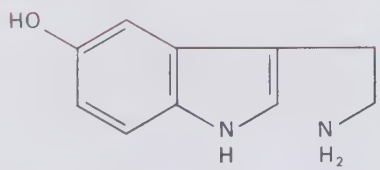
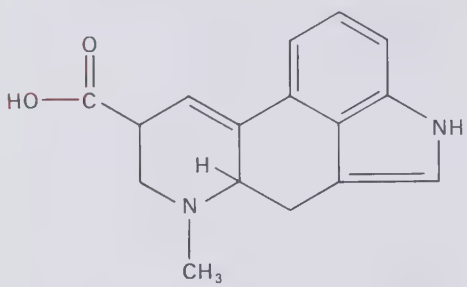
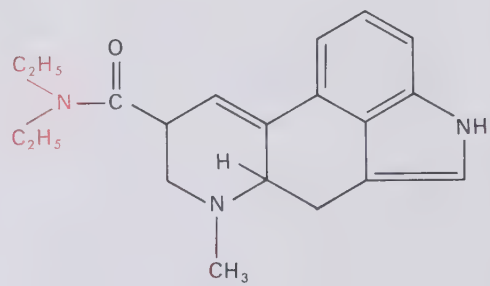


Figure 8-7 (above). Serotonin (5-hydroxytryptamine) may be one of the brain chemicals that transfer signals from cell to cell.



Lysergic acid



d-lysergic acid diethylamide (LSD)

According to one theory, an LSD molecule can fool a nerve cell into accepting it as a signal-carrying serotonin molecule. LSD, however, cannot forward messages (impulses) the way serotonin does, so signals are altered. Thus, the molecule may both increase the number of signals and also distort signals so that sensations received are exaggerated (see Figure 8-8).

LSD was synthesized in 1928 from lysergic acid in ergot, a fungus that grows on rye plants. The removal of the ethyl groups (—C_2H_5) from the "acid" molecule decreases the hallucinogenic power of the alkaloid. The

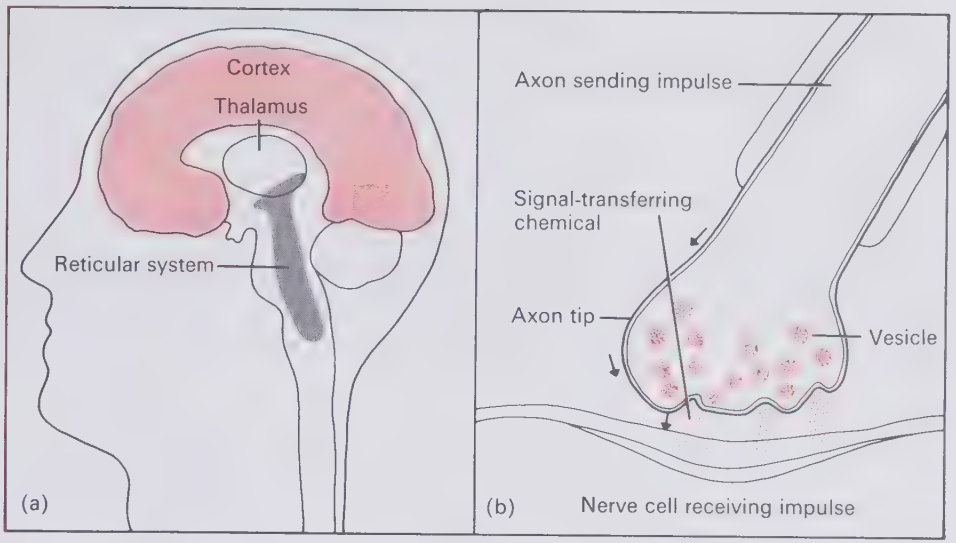
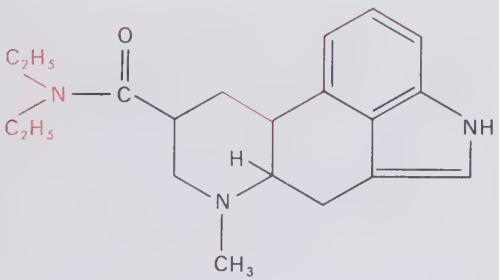


Figure 8-8. LSD affects some of the brain areas shown in (a). In (b) is shown the normal transference of signals from axons to nerve cells. The LSD molecule appears to interfere with this transference of signals.



Dihydro-LSD

Figure 8-9. The removal of a double bond from LSD results in marked changes in its action on the body. Dihydro-LSD has little hallucinogenic activity.

removal of the double bond to form dihydro-LSD (see Figure 8-9) results in marked changes in the action of LSD on the body. The dihydro-LSD molecule produces little hallucinogenic activity.

Man's use and abuse of these molecules to manipulate his mind has often involved these chemicals with superstition. The intelligent use of some "mood modifiers" may result from increased scientific study. As our knowledge increases, we may be able to end drug abuse.

Figure 8-10. Drug research continues round the world in laboratories such as this Canadian one. Some laboratories will permit visits from organized groups of students.

9

Pain and fever killers

When God made woman from one of Adam's ribs, we are told in the Bible, Adam was first sent into a deep sleep—presumably so that he would feel no pain during this major surgical operation. Since the beginning of time, the problem of pain has concerned man and a great deal of thought has been given to discovering ways and molecules to lessen suffering.

Everyone in good health can feel pain. Pain consists of signals from sensitive nerve endings in the skin (see page 5) and from fibres covering the internal organs (e.g., heart, lungs, kidneys, intestine, uterus). As these signals travel towards the brain, they may leap from one pathway to another. When enough signals have reached the brain, a person's "pain threshold" has been reached. Many factors such as sex, skin temperature, sweating, carbon dioxide, anxiety, fear, and emotion alter the pain threshold.

Many molecules have been made to modify and sort out the pain signals as they approach the brain. The molecules in the group that can put you to sleep to relieve pain are called anaesthetics. Analgesics, on the other hand, relieve milder pain without putting you to sleep.

Aspirin

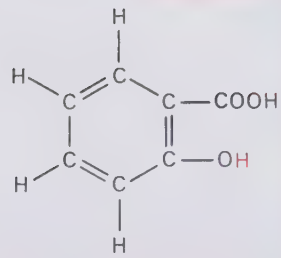


Figure 9-1. Salicylic acid. Because it irritates the stomach, salicylic acid is used externally on the skin, to treat warts, corns, and fungal infections.

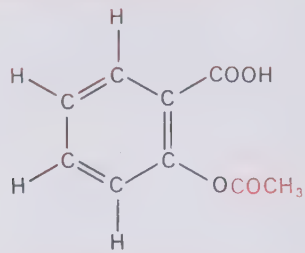


Figure 9-2. Acetylsalicylic acid (aspirin, or ASA). Notice the similar chemical structures of salicylic acid and aspirin. "Acetyl-" refers to the presence of $COCH_3$ in molecules.

Over 2000 years ago in Greece, Hippocrates prescribed the bark of a willow tree to relieve pain and fever. In 1876, salicylic acid (Figure 9-1) was made by man and used to relieve fever. However, this substance also caused severe stomach upset and sometimes bleeding in the stomach. In 1899, K. Hofmann reduced this unwanted side effect by slightly altering the chemical structure of the molecule. He produced acetylsalicylic acid (ASA), which he called "aspirin" (see Figure 9-2). Today, aspirin is the best-known and most widely-used mild analgesic and is an excellent example of how a small change in chemical structure can change the action of a drug. The same is true of many of the modern pain killers.

Aspirin has three main actions: it relieves pain, lowers temperature, and reduces inflammation. It works well against the less severe pains, like headache and bone and muscle pain, but has little effect on pain in the internal organs or intense pain following surgery.

Have you ever noticed an odour of vinegar when you open a bottle of aspirin? Why does this happen? When aspirin is exposed to moisture, even moisture in the air, the acetylsalicylic acid separates into acetic acid (vinegar) and salicylic acid (as illustrated in Figure 9-3). The odour of vinegar then becomes noticeable. Aspirin appears as white needle-like crystals or as a powder, with a faint smell. It is stable in dry air.

A common complaint is, "aspirin causes a burning in my stomach." This is due to the corrosive action of the salicylic acid on the stomach walls. To avoid the burning you should take aspirin with milk. To reduce this unwanted side effect of aspirin, less irritating kinds of ASA have been made. Some dissolve very quickly to form a solution, some only release the active molecule slowly, while others are said to be "*buffered*" to neutralize the acid.

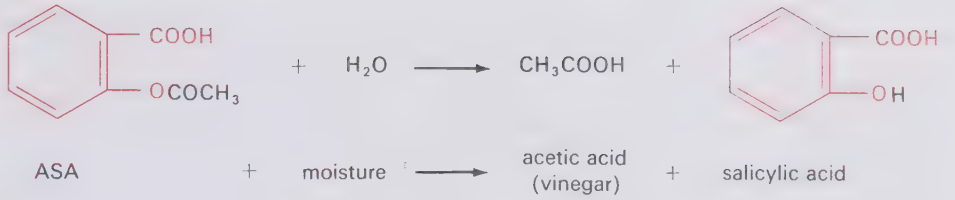


Figure 9-3. The separation of ASA by the presence of moisture.

Of all the medicines known to man, perhaps none is more widely used than aspirin. Since 1900, millions of ASA tablets have been taken to relieve headaches and cold symptoms, help fight fevers, and to ease the pain of arthritis. The search for other pain-relieving substances continues.

• *Experiment 9.1*
What is in headache tablets?

Materials:

(a) Bottles of ASA tablets
(b) Bottle of aspirin tablets
(c) Bottle of children's aspirin
(d) Balance

Method:

(1) Obtain at least 3 bottles of ASA or ASA in combination. Set up a chart in your notebook, then read and record the label claims with respect to ASA. Here is a chart you could use.

Tablet	Label statement of ASA content	Mass of tablet (g)
Acetylsalicylic acid (ASA)		
Aspirin		
Children's aspirin		
ASA and other ingredients		
Other tablets with ASA (for example ASA enteric-coated, or buffered ASA)		

(2) Take the mass of 1 tablet from each bottle. (Note: 15.432 grains equal 1 g.)
(3) Compare the actual masses of your tablets with the masses stated on the labels. Compare your results with those of your classmates. What is in an ASA or aspirin tablet?
(4) You can extract ASA from, say, 5 tablets using the fact that 1 g of ASA dissolves in 300 cm^3 of water or in 5 cm^3 of ethanol.

The name "aspirin" comes from Spirsäure, the German word for salicylic acid.

Most tablets and capsules have contents other than just the active substance. These include:

binders to keep the tablet together;
fillers to give the tablet bulk;
additives for colour and flavouring.

All ingredients in a preparation must conform to strict standards of the Health Protection Branch of the Federal Department of National Health and Welfare.

Experiment 9.2 Making acetylsalicylic acid (aspirin)

Materials:

(a) Erlenmeyer flask
(b) Salicylic acid
(c) Acetic anhydride*
(d) Concentrated sulphuric acid*
(e) Thermometer
(f) Glacial (concentrated) acetic acid*
(g) Filtering apparatus (Buchner funnel is best)
(h) Ice

*These chemicals can cause severe burns on skin and clothing. Handle with care.

Method:

(1) Add, in order, to an Erlenmeyer flask: 5 g of salicylic acid, 10 cm^3 of acetic anhydride and 1 to 2 cm^3 (20 to 40 drops) of concentrated sulphuric acid.
(2) Stir the mixture, and note the rise in temperature.
(3) Continue stirring the contents of the flask for about 10 minutes, or until the temperature has decreased to about 25°C.
(4) Add 10 cm^3 of cold glacial acetic acid, cool the mixture in an ice bath and collect the crystals in a funnel fitted with filter paper.
(5) Wash the crystals on the filter paper with a little cold water, and allow to dry.

Pure aspirin melts at 135°C. You may wish to determine the melting point of the aspirin crystals which you prepared. How pure are they?

Figure 9-4. When are you likely to get a headache? The clocks summarize the results of one study.

10

Over-the-counter (OTC) medicines

Sneezes and wheezes

As spring turns to summer, many people look forward to the long evenings, holidays in the country, or to a summer job. But to the hay fever sufferer and the asthmatic, the lazy, pollen-filled days bring discomfort and even danger. Hay fever produces sneezing, a continuously running nose, itchiness (especially in the eyes), and inflammation. The asthmatic also wheezes and has difficulty in breathing. The usual cause of these *allergic* reactions is pollen measuring only 3/100 mm in diameter.Tiny particles fall on sensitive cells, triggering the release of a body chemical, histamine.

Histamine

Histamine is a chemical substance found in almost every tissue of your body. The action of this powerful chemical dilates (opens) your small blood vessels (capillaries and arterioles), producing a flushing of the face, a fall in blood pressure, and an increase in skin temperature. Histamine is present in large amounts in the cells of the human skin but is "locked up" and under ordinary conditions does not escape into the general circulation. It is believed, however, that the redness and swelling that follow, say, a pin scratch or sunburn, are caused by histamine or a histamine-like substance that the injury has caused to be freed from the cells of the skin.

Antihistamines

Antihistamines fight the effects of histamine. They are useful in treating itching, running nose and eyes, allergies like hay fever, cold symptoms, and reactions to some antibiotics. It is important to note that antihistamines treat the symptoms rather than the actual causes. That is, these molecules treat the running nose and eye, which may be associated with hay fever, but not the actual cause of the allergy.

Most of the molecules mentioned so far in this booklet you can get only on a doctor's prescription. Some, for instance LSD, are not legally available to the public, but others can be bought "over-the-counter" at a pharmacy. Visit your local drug store and make a list of, say, ten to twenty different OTC medicines, their contents, uses, recommended dosages, and cautions against side effects. If you check the labels of OTC antihistamines you will probably notice that they may all cause drowsiness. You should, therefore, be careful about driving after taking antihistamines.

In 1972, 92 274 080 medical prescriptions were made out in Canada. The average cost per prescription was $4.25.

Here are some OTC items.
Cough and cold preparations (lozenges, antihistamines)
First-aid products
Vitamins
Antacids
Haemorrhoid preparations
Pain relievers

Upset stomach?—antacids

The *antacids* are one of the largest groups of OTC medicines in a pharmacy. The antacid molecules react with the hydrochloric acid in your stomach to lower the acidity (raise the pH). You know that some substances like lemon juice are acid and have a sour taste, while others are either alkaline (for example, milk) or neutral. If the normal acidity or alkalinity is upset, the various chemical reactions are affected. For example, in the mouth the saliva will digest starch if the pH is between 5.6 and 7.6. If it is lower, the acid will

attack the teeth. If it is higher, no digestion will take place. The action of the saliva will eventually be stopped in the stomach, where the gastric juice has a rather low pH value (about 2). Figure 10-1 shows the pH of some of the fluids produced by the body. It also gives the pH of lye, which is used as a drain cleaner.

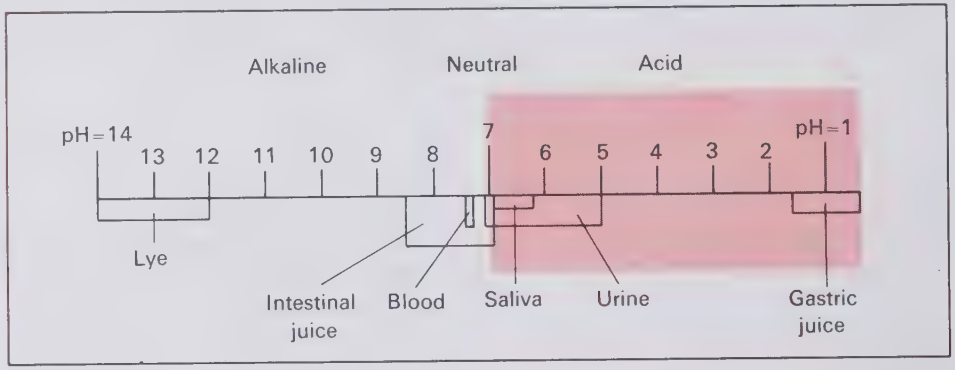


Figure 10-1. The pH scale. Each division represents a tenfold change in acidity or alkalinity. For example, pH 4 is ten times as acid as pH 5.

An increase in stomach acidity can lead to corrosion of the stomach lining and possibly ulcers. Antacids used to correct such sicknesses have been experimentally compared according to their ability to neutralize a given quantity of acid. For instance:

Magnesium oxide	3	Magnesium carbonate	7	Bismuth	
Sodium bicarbonate	12	Calcium carbonate	7	subcarbonate	136

Mass for mass, therefore, magnesium oxide works four times better than sodium bicarbonate, while bismuth subcarbonate has relatively little effect. That is, the larger the number the more antacid is required to neutralize the acid.

Match these chemical formulas with the name of the antacid.

$MgCO_3$	MgO
$CaCO_3$	$NaHCO_3$
$(BiO)_2CO_3$	

Experiment 10.1 Acid-neutralizing properties of antacids

How effective are OTC antacids in neutralizing acid? How do they compare with each other?

Materials:

(a) Balance
(b) 250 cm^3 beakers (4)
(c) Wash bottle
(d) 50 cm^3 burette
(e) Burette clamp, ring stand
(f) Stirring rod
(g) pH meter or other acid-base indicator
(h) 0.15 M HCl (about equal to the concentration of HCl in gastric stomach juice)
(i) Universal indicator solution
(j) Antacid tablets (several commercial brands) and knife

Figure 10-2. A student compares the effectiveness of antacid tablets (Experiment 10.1).

Method:

(1) Place a tablet on a clean surface and split it into quarters using a knife or single-edged razor blade. Place each quarter into beakers of known mass and find the mass of the sample by taking the mass of the empty beakers from the mass of the beakers and tablet quarters.
(2) Add about 100 cm^3 of distilled water to each beaker and try to dissolve the sample as much as possible by crushing and stirring. (Because the active ingredients and the tablet filler will probably be largely insoluble in water, the material in the beakers will be a greyish-white suspension rather than a true solution.)
(3) Record the pH of the solution. Add a few drops of universal indicator and note the colour.
(4) Clean and rinse the burette and fill it with the 0.15 M HCl. Record the initial burette volume ± 0.01 cm^3. Begin stirring the solution.
(5) Slowly add acid from the burette in small portions until the pH of the solution has been reduced to 2.0, the approximate pH of gastric juice. At this point, the colour of the indicator should be pink. Record the final burette volume reading.
(6) Repeat (1) to (5) with the other tablet quarters and with other antacids, and average the results. Tabulate your results as below.

	Sample 1	Sample 2	Sample 3
Mass of empty beaker			
Mass of beaker and quarter of antacid sample			
Mass of antacid sample			
pH of "solution" at start			
Colour of solution with indicator at start			
Initial burette volume			
Final burette volume (pH 2.0)			
Volume of 0.15 M HCl used			

Which tablet appears to be the best neutralizer of 0.15 M HCl? You can calculate the most economical brand by using the following formula:

$$\frac{\text{cm}^3 \text{ acid neutralized by tablet}}{\text{g of tablet}} \times \frac{\text{g of tablet}}{\text{penny}} = \frac{\text{cm}^3 \text{ of acid neutralized}}{\text{penny}}$$

So, if 100 tablets cost \$2.00, then

$$\frac{15 \text{ cm}^3}{0.50 \text{ g}} \times \frac{0.25 \text{ g}}{1¢} = \frac{7.50 \text{ cm}^3}{1¢}$$

Therefore, one cent's worth of tablet neutralized 7.5 cm^3 of acid.

11

1 + 1 = 3: medicines in combination

Here are some precautions issued by a manufacturer regarding the taking of one of their drugs with other molecules. When using drug X, don't eat: broad beans, sour cream, pickled herrings, chicken livers, canned figs, raisins, chocolate, or soy sauce. Also, don't drink alcoholic beverages.

● *Project 11.1 OTC preparations and their contents*

Breathalyzer

By now you will have realized that man has created many powerful molecular weapons to help keep you healthy. You have seen how some of these medicines can easily do more harm than good if wrongly used. What may happen if you take more than one medicine or ingredient to cure an illness?

When two molecules with a similar effect are taken together you might expect a greater effect than that of either medicine taken alone. The terms additive, superadditive, and potentiation have been used to describe the results of medicines taken in combination. (Refer to Table 11-1.)

Table 11-1 MIXING YOUR MOLECULES

Situation	Mathematical representation	Term
Combination of 2 medicines or ingredients does not increase the common effect of either ingredient used alone	2 + 2 = 2	No additive effect
Equivalent doses of each ingredient produce the same effect as a double dose of either used alone	2 + 2 = 4	Additive effect
Ingredients A and B taken together have less effect than double the dose of one	2 + 2 = 3	Less than additive effect
Ingredients A and B taken together have a greater effect than a double dose of one (> means "greater than")	2 + 2 > 4	Superadditive effect
Ingredients A and B have more effect together than the normal effect of of one of them alone	2 + 0 > 2	Potentiation

To gain a better appreciation of the variety of molecules available alone and in combination with other molecules, extend your list from Chapter 10 to include more OTC preparations.

Examples of the effects of molecules in combination are:
alcohol + barbiturates = additive and sometimes superadditive;
alcohol with major tranquillizers = superadditive; and
alcohol with antihistamines = additive.

Molecules, particularly if taken in combination, are a factor in many traffic and industrial accidents.

Over half of all traffic accidents are at least partly due to alcohol, or to some other drug and usually alcohol plus some other medicine. The "breathalyzer test" is given to drivers thought to be "under the influence of alcohol."

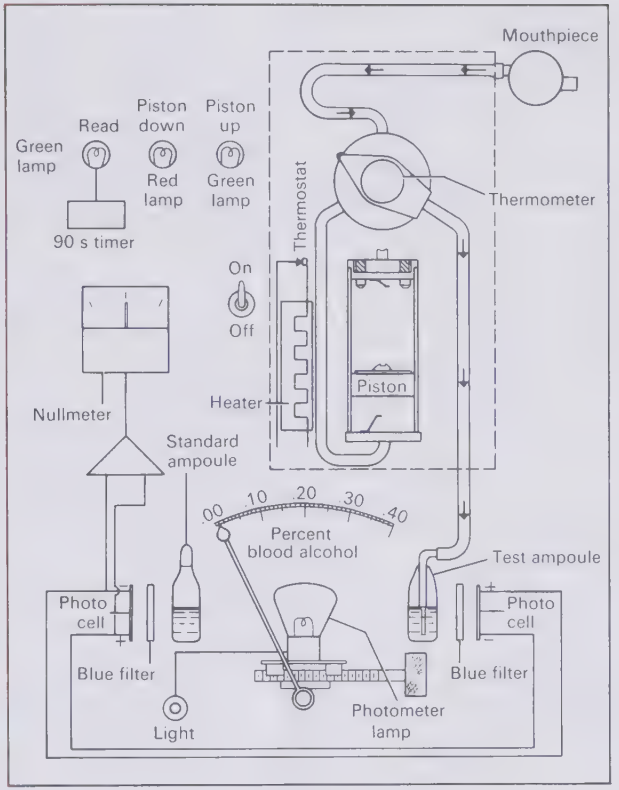
CHEMICAL REACTION OF THE SOLUTION IN THE BREATHALYZER

Potassium dichromate + sulphuric acid + alcohol → Chromic sulphate + potassium sulphate + acetic acid + water

Yellow → Green

$2K_2Cr_2O_7 + 8H_2SO_4 + 3C_2H_5OH = 2Cr_2(SO_4)_3 + 2K_2SO_4 + 3CH_3COOH + 11H_2O$

Figure 11-1. How a breathalyzer works. If you blow into the mouthpiece, your breath enters a glass test ampoule containing potassium dichromate and sulphuric acid. Any alcohol in your breath will react chemically with the contents of the test ampoule, the colour of which will change from yellow to green. The greater the "per cent blood alcohol," the more the meter needle will swing right.



The breathalyzer (Figure 11-1) is a small instrument that can analyse how much of your breath is alcohol. A reading on the breathalyzer scale above 0.08 is taken as a serious body alcohol content for a driver. A driver should wait one hour per drink before driving a vehicle.

The LeDain Commission, in its enquiry into the non-medical use of drugs, suggests that alcohol is misused by more people than any other drug.

Other combinations of ingredients often produce unusual reactions:

aspirin + antidiabetic agents = potentiation;

antihistamines + OTC sedatives = potentiation of depression.

Results of a 1969 study indicate that users of oral contraceptives who are heavy smokers have an incidence of blood clots twenty-three times that of women who neither smoke nor use the pill. Cigarettes may potentiate the role of oral contraceptives in producing clots.

Many people take several medicines to treat single or multiple sicknesses. These combinations, together with the chance that the person might drink and smoke, greatly increase the hazards of combining molecules.

12

1000 Einsteins, 1000 Hitlers — or, "Where are we going?"

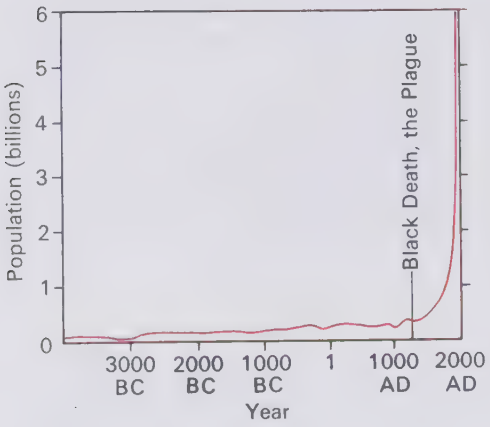


Figure 12-1. Growth of the human population. It took hundreds of thousands of years for man to multiply to about three billion people in 1960. But by the year 2001 or so, the earth's population will probably grow to six or seven billion.

We're living longer, partly because man has been so successful in combining atoms to make him healthier. Figure 2-1 shows you how spectacularly deaths from certain diseases have been reduced, thanks partly to medicinal molecules. This and other factors have led to a very rapid growth in world population, as is indicated in Figure 12-1. Where do we go now? Here is one forecast from the Office of Health Economics in England made by a panel of forty experts from six countries, including Canada.

1970s

*Effective anti-viral drugs likely to be available.
*Birth control using "male pills," "morning after" pills, long-acting pills.
*Medicines to "burn off" excess calories—slimming.
*Specific enzymes to prevent formation of blood clots.
*Increased range of antibiotics.
*Improved short-acting anaesthetics.
*Medicines to reduce cholesterol.
*Diabetes should be completely and reliably controlled by oral medicines.
*An improved serum available for organ transplants.
*Compounds available to speed up learning, to improve co-ordination, to fight stress and fatigue, to improve or modify man's perception of his surroundings.
*Influenza vaccination added to routine child immunization.
*Drug treatment to prevent death in first critical hour after heart attacks.
*Medicines to alter mood, reduce anxiety without loss of body co-ordination.
*New test tube methods for diagnosing rheumatoid arthritis.
*Reduction of abnormalities at birth.
*Possibly naturally occurring anti-cancer compounds specific for certain tumours.

1980

*Significant progress in controlling chronic infections.
*Probably effective medicines for control of high blood pressure.
*More efficient and specific medicines for mental disorders.
*Definite progress in control and prevention of syphilis.
*Fewer people requiring kidney transplants.
*Specific substances to control most allergic conditions.

1985

*Ageing process delayed, even partially reversed to increase length of life.
*Correction of inborn disorders of metabolism affecting brain function.

*Substances developed to improve man's natural resistance to infection.
*Specific medicines for schizophrenia.
*Ways of preventing coronary heart disease will have been explored.
*Epilepsy and migraine eliminated.
*Prevention of certain brain diseases may be possible.
*Seventy per cent of cancers will be controllable.
*Broad-spectrum anti-viral compounds.

1990

*Medicines to make the old look young.
*Artificial hearts should be perfected.
*Improved understanding of and perhaps prevention of some muscular disorders.
*Ability to forecast heart attacks, and drugs to reduce chances of dying from these attacks.

What do *you* think about the future of man and his molecules? What is *your* forecast for the chemistry of man and molecules?

SI units conversion chart

SI UNITS				
	Name	SI unit	Derived SI unit	Equivalent
Length	Kilometre	—	1 km	0.621 mile
	Metre	1 m	—	3.28 ft
	Centimetre	—	1 cm	0.394 in
Area	Square metre	1 m^2	—	10.76 ft^2
	Hectare	—	1 ha	2.47 acres
Volume	Cubic metre	1 m^3	—	35.3 ft^3
	Cubic centimetre	—	1 cm^3	0.061 in^3
	Litre (= 1000 cm^3)	—	1 l	1.050qt
Mass	Kilogram	1 kg	—	2.205 lb
	Gram	—	1 g	0.035 oz
Energy	Joule	1 J	—	0.238 cal
Pressure	Pascal	1 Pa	—	0.000 145 lb /in^2
	Megapascal	—	1 MPa	9.87 atm
Time	Second	1 s	—	1 sec

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Films

The following 16 mm films are available from the Addiction Research Foundation, 33 Russell Street, Toronto, Ontario M5S 2S1.

"Alcohol: How much is too much?" Colour, 12 minutes, 1972.

"Drugs and the Nervous System." Colour, 18 minutes, 1972. (Explains how drugs affect many different parts of the body by working indirectly on the nervous system.)

"Point Zero Eight." Black and white, 30 minutes, 1966. (This film views a day's testing of the driving ability of professional racing drivers, before and after drinking various amounts of alcohol.)

"Two Festivals." Black and white, 6 minutes, 1972. (Descriptive film. No dialogue, but with a music background to scenes from "Octoberfest" and a rock festival.)

Special Materials for experiments

This list is of special materials not normally stocked in a school laboratory, but which would be needed for a class of thirty students to complete all the experiments in this book.

Chapter 1
Quinine sulphate (One 200 mg capsule)

Chapter 2
Agar (3 g)
Beef or chicken soup cubes (10)
Cotton swabs (50-100)
Methylene blue solution (150 cm^3)
Peptone (7 g)
Petri dishes (50-150)
Potassium di-hydrogen phosphate (3 g)

Chapter 3
Benzene (200 cm^3)
Buchner funnels (5-15)
Dichloromethane (1200 cm^3)
Heating elements, no flames (5-15)
Lead acetate (40 g)
Petroleum ether (350 cm^3)
Separatory funnels, 400 cm^3 (15)

Chapter 5
Sodium dichloroindophenol (150 mg)

Chapter 6
Oven (1-2)

Chapter 7
Pipe cleaners (box of 100)
Plasticine, different colours (45 strips)
Styrofoam spheres (60-100)
Toothpicks (box)

Chapter 9
Acetic anhydride (200 cm^3)
Buchner funnels (5-15)
Salicylic acid (100 g)

Chapter 10
Universal indicator solution (100 cm^3)

Word meanings

Alkaloids	Drugs containing nitrogen. They are basic (alkaline).
Allergy	Excessive sensitivity toward certain substances, e.g., pollen in hay fever, that do not affect most people.
Amphetamines	Drugs that cause marked stimulation of the central nervous system.
Antacid	Agent used to counteract effects of acids.
Antihistamines	Group of molecules that reduces the effects of the body chemical, histamine.
Barbiturate	Any of a number of drugs obtained from barbituric acid and producing sleep or sedation.
Depressant	Medicine that reduces functional activity or decreases physiological activity of the body, such as a barbiturate producing sedation and sleep.
Drug	Any substance other than air, water, or food that affects body structure or function.
Drug abuse	Wrong use, particularly excessive use, of a drug.
Hallucinogenic	The ability to produce an unreal state, such as "seeing," "hearing," or "feeling" things that are not there.
Hypnotic	An agent that induces sleep.
Medicine	A substance, especially one taken internally, to restore good health.
Narcotic	Any drug that produces sleep or stupor and relieves pain and anxiety.
Nerves	Cablelike structures composed of axons, dendrites, or both. Carry sensory and reaction signals from one part of the body to another.
Nutrient (food)	Any substance that may supply energy or be stored for future use, or can repair living materials in the cell.
Physiological dependence (addiction)	A strong need or desire by the body to continue use of a drug, and to obtain it by any means in order to avoid physical discomfort.
Physiology	The study of the functions or activities of the various parts of the body.
Prescription	A direction (written or verbal) by a doctor regarding the type and use of a drug or treatment.
Psychological dependence (habit formation)	A strong *mental* urge or desire to continue the use of a drug.
Sedative	An agent that quiets or calms activity.
Side effects	A given drug may have many actions on the body. Usually one or two of the main actions will be medically useful. The other, usually weaker, effects are called side-effects.
Steroid	Drugs belonging to a group of molecules whose general structure is similar to the illustration on page 26.
Tolerance	The situation in which larger doses of a drug are needed to get the ordinary reaction.
Tranquillizer	An agent that relieves tension and anxiety without producing sleep.
Virus (plural, viruses)	An infecting agent that, unlike bacteria, multiplies only within cells. Viruses are much smaller than bacteria.

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Chemistry of man and molecules
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ISBN 0-7725-2002-X